A QUANTITATIVE STUDY OF RHYTHM

THE EFFECT OF VARIATIONS IN INTENSITY, RATE AND DURATION

BY

HERBERT WOODROW, A.M.

Lecturer in Barnard College, Columbia University

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE FACULTY OF PHILOSOPHY, COLUMBIA UNIVERSITY

REPRINTED FROM THE ARCHIVES OF PSYCHOLOGY, NO. 14

NEW YORK
THE SCIENCE PRESS
1909

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CONTENTS

CHAPTER I

Historical

To produce an impression of rhythm, it is necessary to have a series of stimuli. These stimuli may be sounds, as in the case of poetry and music, muscular contractions, as in dancing and beating time, or lights and electrical shocks, as in some laboratory experiments. The stimuli which give the impression of rhythm, whatever their nature, may vary in intensity, in duration, and in quality, and may be separated by intervals of varying length. A fundamental task of the experimental investigation of rhythm is to investigate the part played by each of these factors. Only after each of them has been studied separately, may we study the effect when two or more of them are simultaneously involved, and when more complicated factors are introduced, as in melody and harmony.

The aim of the present study is to examine quantitatively the dependence of the rhythmical impression on the intensity and duration of the stimuli. Such an investigation is evidently along the same lines as much of the experimental work of Meumann, Bolton, R. McDougall, and others, who have studied the objective conditions of rhythm. It is necessary, therefore, to review the work that has already been done on the perception of rhythm as influenced by variations in the intensity and the duration of the stimuli.

Meumann[1] found that in listening to a series of sounds, some of which were louder than others, there was a strong tendency towards the formation of rhythmical groups. He studied the effect of accented sounds on the intervals preceding and following them. The most general conclusion at which he arrived is that the effect of the more intense sound may be very different according to its position in the rhythmical group.[2] He found that sometimes the interval following the accented sound is overestimated and sometimes underestimated, and also that sometimes the interval preceding the accented sound is overestimated and sometimes underestimated, and in the cases in which he used more than one subject, he gets quite different results under the same objective conditions. Meumann states, also, that, with *most* subjects, the sudden introduction of a loud sound into a series of weaker ones causes an underestimation of the interval preceding, and an overestimation of the interval following, the loud sound;[3] but he does not

[1] *Philos. Stud.*, 9, 264–306, 1894.
[2] *Ibid.*, 9, 303 and 10, 311, 1894.
[3] *Ibid.*, 9, 276, 1894.

say how many observers gave this introspection, what was the introspection of those who did not give it, how many judgments were made by each observer, or how they were instructed. Meumann made no investigation of the effect of duration in rhythm.

Bolton[1] presented sets of sounds of different intensities and durations, which recurred always in the same order, and asked the subject to point out where the series was grouped. In this way, he sought to determine what was the most natural order in which the different intensities and durations occurred in the group. These experiments led him to state the following general principle: "In a series of auditory impressions, any regularly recurrent impression which is different from the rest, subordinates the other impressions to it, in such a way that they fall together in groups. If the recurrent difference is one of intensity, the strongest impression comes first in the group and the weaker ones after. If the recurrent difference is one of duration, the longest impression comes last."[2]

Bolton calls attention, further, to the long interval which appeared between the groups, the intervals being objectively equal. The pause seemed to be due to the fact that a long interval generally preceded the accented sound. At the same time some subjects, especially 10 and 15, make a short interval after the strongest sound. But in another place, Bolton writes: "The accented long sound frequently appeared more prolonged than the unaccented of the same length: the accent had the effect both to increase the length of sound and of the interval which followed." And consulting his table of results,[3] we find that his subjects often found the interval preceding the accented sound longer than the others, but more often did not. As regards the effect of duration, most of Bolton's subjects remarked upon the long interval or pause which seemed to follow the long sound, and for this reason it was found difficult to make the close of the group come at any other place.

Ettlinger[4] has criticized Bolton for his tendency to generalize his results on duration, which, being limited to the single case in which one sound is twice the duration of the other, do not permit of much generalization. So far as they go, however, his results indicate that the effect of increasing the length of any regularly recurrent sound is to produce an overestimation of the following

[1] *Amer. J. of Psychol.*, **6**, 222, 1894.
[2] *Ibid.*, p. 232.
[3] *Ibid.*, p. 228.
[4] *Ztschr. f. Psychol.*, **22**, 132–133, 1900.

interval, while the effect of increasing the intensity is uncertain. To most of Bolton's subjects, the strongest sound seemed longer than the rest, and the long sound frequently seemed accented.

Schumann[1] asked his subjects to compare the second of two intervals enclosed within a series of three sounds with the first interval. He found, in the case of four subjects, that when the third sound was louder than the preceding, the second interval was underestimated as compared with the first. Three of those same subjects were also tested with regard to the effect of a loud sound which was unexpectedly introduced in a series of weaker sounds. In the case of all three, the interval preceding the louder sound was apparently shorter than the other intervals. Two subjects, on the other hand, obtained the opposite result in both experiments, that is, the interval preceding the accent was overestimated as compared with the other intervals. Schumann explains this apparent contradiction on the ground that the two last mentioned subjects perceived the sounds rhythmically. He made no investigation of the effect of the regular recurrence of a more intense sound every second or every third time in a long series, nor did he study the effect of variation in the durations of sounds on rhythm or on the judgment of intervals.

McDougall[2] found that a loud sound introduced into a uniform series of six beats causes a considerable underestimation of the interval following the loud sound, while it less often and less considerably lengthens the preceding interval. As regards the overestimation of the interval preceding the accent, of the four tables[3] of results which are presented to prove this, one[4] shows an underestimation; another[5] shows practically no constant error, but an underestimation rather than an overestimation, while a third[6] does not show that accent has any effect on the interval immediately preceding, but that a longer interval causes overestimation of the interval preceding that longer interval. As regards underestimation of the interval following the accented sound, we find one table[7] which shows that when the interval following was 20 per cent. shorter than the interval preceding the accent, and 10 per cent. shorter than the remaining intervals, it was judged less than the remaining intervals 26 times,

[1] *Ztschr. f. Psychol.*, 18, 30–36, 1898.
[2] *Harvard Psychol. Stud.*, 1; *Monog. Sup. Psychol. Rev.*, 4, 309–412, 1903.
[3] *Op. cit.*, Tables XXVIII, XXIX, XXXI and XXXII.
[4] Table XXIX.
[5] Table XXXI.
[6] Table XXXII.
[7] Table XXIX.

but as equal to them 31 times, and greater six times. The table shows, therefore, that the interval following the accented sound, which was 10 per cent. less than any of the other intervals, was judged either equal or greater in 59 per cent. of the cases. This is about as strong evidence of overestimation as the other three tables give of underestimation. Still more doubt is thrown upon McDougall's conclusion in this connection from the fact that, though five subjects are said to have participated in the experiments represented in these four tables, no separate record is kept of these individuals, and even then the total number of judgments on any one set of intervals is very often not over six. These experiments were made as already stated with series of six sounds, one of which was louder than the others. Other experiments were made by McDougall in which series which might be called rhythmical were presented to the subject, that is, series in which the accented sound recurred regularly every other time or every third time. In these, it is quite evident that the interval preceding the accented sound is overestimated as compared with the other intervals. McDougall moreover determines the magnitude of this relative overestimation of the interval preceding accent in rhythmical groups of both two and three sounds. To accomplish this, he ascertained at what temporal spacing the grouping disappeared, that is, what relative length of the intervals before and after the accented sound was necessary to produce the impression of temporal uniformity in the series. He refers to the point at which temporal uniformity takes the place of rhythmical grouping as the indifference point. Concerning this point, he writes: "At a certain definite stage in the process the tendencies toward the two forms of apprehension balance each other, so that with the slightest change in direction of attention the rhythmical figure inverts and reverts to the original form indifferently."[1] As regards the effect of duration, McDougall made no investigations corresponding to those on intensity.

Miner[2] investigated the effect of intensity and of duration in visual rhythms, using lights in place of sounds. His subjects mistook a difference in the duration of the lights for one of intensity. The more intense light regularly recurred every second or every third time. The intervals between the lights were always equal. The subjects were asked to group the lights first, in groups in which the brighter came first, and second, in groups in which the brighter came second. While doing this, they had, further, to judge which interval was the longer, and which the shorter. We have no guaran-

[1] *Op. cit.*, p. 382.

[2] *Monog. Sup. Psychol. Rev.*, 5, No. 4, 1903.

tee that the subjects actually held to this forced rhythm while observing the relative length of the intervals. In fact, Miner, himself, distinguishes two attitudes on the part of these subjects, though all were similarly instructed. These attitudes he calls the rhythmical and non-rhythmical. He reports no introspections, however, on the part of the subjects, on which to base this division of them into rhythmical and non-rhythmical, and it is made merely as an explanation of the disagreement between the results of different individuals. His results do not admit of much generalization. The following statements, however, can be made. The interval which was most often judged the longest, no matter how the sounds were grouped, was that which separated the groups. The interval next most frequently judged the longest was that before the brighter light. Like Meumann, Schumann, and McDougall, Miner also investigated the effect of only one intense stimulus in a longer series of less intense. He found that twelve out of seventeen subjects judged the interval after the bright flash to be the longer.

Miner says that the discrepancy between his own results and those of McDougall may be due to the difference in the quality of the stimulus or the length of the intervals. But this would not explain the discrepancy between Meumann's statements and those of McDougall. Of more importance, probably, is the fact that, in Miner's experiments, the subjects did not know at what point in the series to expect the intense stimulus, whereas, in McDougall's, they did. Miner says that the bright flash was brought in at an unexpected time. Moreover, the subjects were told to notice any difference in the appearance of the interval or the light that followed the bright flash, that is, their attention was directed to the interval and stimulus following the more intense stimulus. With such instructions, we do not know whether the interval following the brighter light appeared longer because of the brighter light or because the subject's attention had been specially directed to the interval and light following the bright flash. McDougall's subjects, on the other hand, knew when the loudest sound was to appear. He writes: "As a single hearing very commonly produced but a confused impression due to what was reported as a condition of unpreparedness . . . . . the method adopted was to repeat each series before asking for a judgment. . . . . In order to define the direction of attention on the part of the observer, it was made known that the factors to be compared were the durations of the intervals adjacent to the louder sound in re-

lation to the remaining intervals of the series."[1] This difference in the instructions given the subjects may account for the difference in the results. In other words, the disagreement between the results of Miner and McDougall may be interpreted as merely a piece of evidence of the importance of the direction of attention in the estimation of intervals. The results of both investigations agree in that they find an overestimation of the interval preceding that stimulus which, there is reason to suppose, is the object of the greatest amount of expectant attention, namely, the more intense, when the subject knows when to expect it,[2] or the one after the more intense, when they are not informed when to expect the more intense, but have had their attention especially directed, as a result of their instructions, to the stimulus following the more intense. The apparent discrepancy between the results of Miner and McDougall, therefore, goes to confirm Schumann's theory concerning the effect of strain of attention in the estimation of small intervals.

Whether Miner's results are to be considered as contradicting those of Bolton on the effect of an increase in duration is not very clear. Miner found that his subjects mistook an increase in the duration of a light for an increase in intensity, and finds that this apparent increase in intensity has about the same effect on the rhythmical grouping as an actual objective increase in the intensity of the stimulus. But as we have already pointed out, Miner's experiments do not permit us to generalize concerning this effect. And, in fact, we have no way of being sure which of the large number of varieties of effect he mentions were due to apparent intensity and which to the attempt of the subjects to group the sounds in the way that they were instructed to group them.

Notwithstanding many apparent contradictions among the investigations I have reviewed, it is yet possible to indicate the general trend of results so far obtained concerning the effect of variations in the duration and intensity of certain stimuli in a series. There

[1] *Monog. Sup. Psychol. Rev.*, 4, 362–363, 1903.

[2] G. F. Arps und O. Klemm, "Der Verlauf der Aufmerksamkeit bei rythmischen Reizen." *Psychol. Stud.*, 4, 518–528, 1909. These authors, using the sensitivity to temporal displacements of each of the members of a dactylic group (every 3rd sound of the objective series being accented and the intervals all equal) as a measure of the degree of attention bestowed on each of the members, conclude that the greatest degree of the attention occurs at the accented sound and the least at the second unaccented sound. The greatest change in the level of attention occurs therefore during the interval preceding the accented sound. Apart from this work we have the generally recognized fact that intensity is one of the "objective conditions" of attention.

can be no question but that the effect of a more intense stimulus in a series of less intense is different, according as the more intense occurs unexpectedly, or at a time when it is expected, as when the more intense stimulus regularly recurs. The general conclusion indicated, if I may neglect, for the sake of simplicity, the special conditions of the above-mentioned researches, is that a more intense stimulus, if unexpected, causes a relative underestimation of the interval preceding it; if expected (or regularly recurrent), a relative underestimation of the interval following it.

As regards duration, about all that can be said, neglecting special conditions again, is that in the case of regularly recurrent differences, one investigator has found an overestimation of the interval preceding the longer stimulus, another, indications of an overestimation of the interval following the longer stimulus.

CHAPTER II

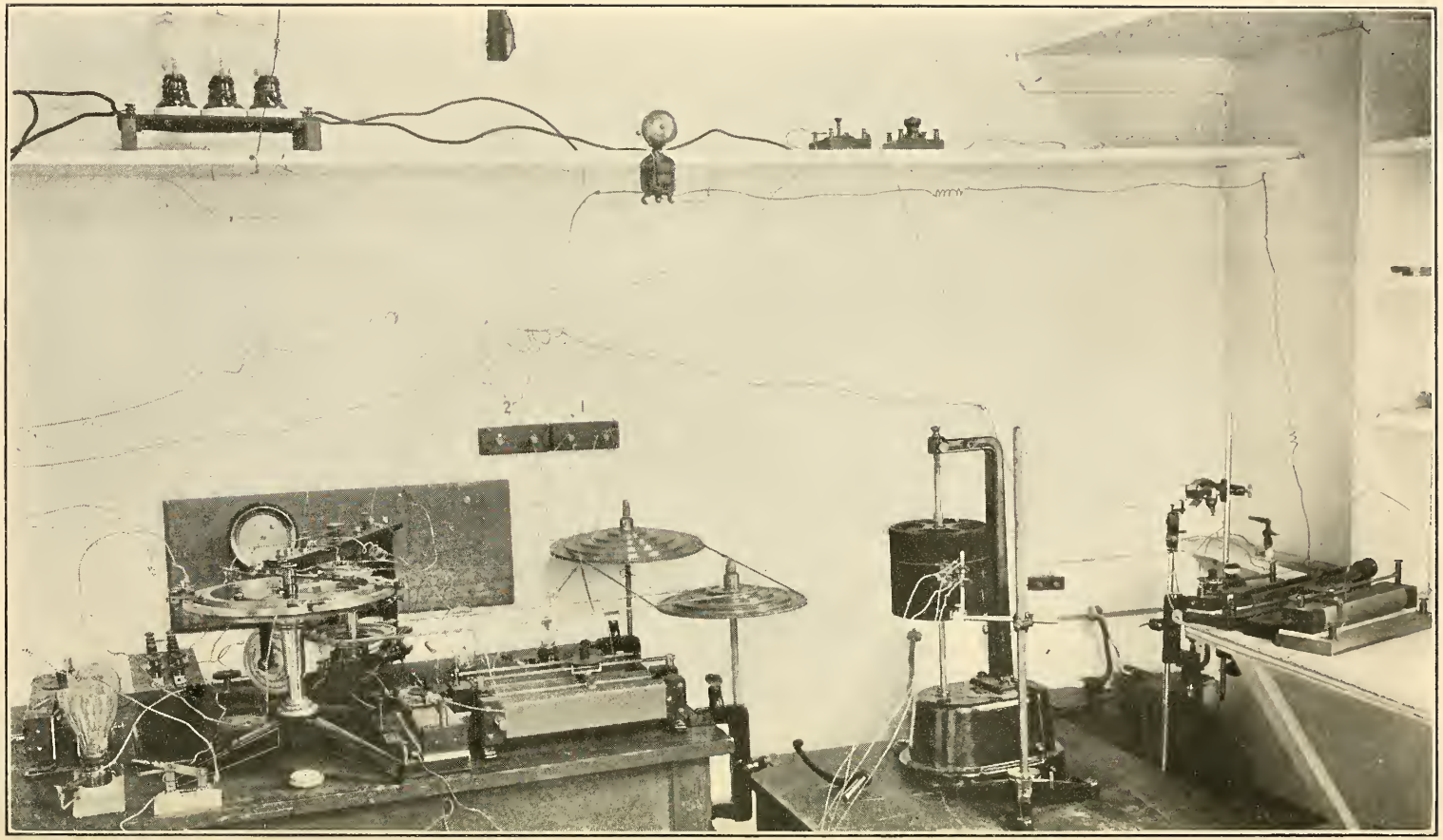
Apparatus and Procedure

The following experiments were performed in the psychological laboratory of the University of Michigan, under the guidance of Professor Pillsbury and Dr. Shepard, whom I am glad to thank for their advice and aid. The work was done mostly during the summer vacations of 1907 and 1908. The subjects used, thirteen in all, were, with one exception, advanced students doing original work in experimental psychology. I take this occasion to express to all those who acted as subjects my appreciation of their patience and conscientiousness.

The first question to be solved, in an investigation of this sort, is how to produce a series of sounds in which it is possible to make accurately measurable variations in the absolute and relative length of the intervals between the sounds, their absolute and relative intensity, their absolute and relative duration, and the relative proportion of sound and silence. I will describe, first, the disposition of apparatus for work in which the effect of intensity was studied and then point out the changes that were necessary for the study of variations in the duration of the sounds and their rate of succession.

Part of the apparatus used in the production of the series of intensively changeable sounds is shown in the cut, opposite page 13, which represents the operator's room. In addition, there was in the subject's room a telephone, head-rest, and a microscope for reading the amplitude of vibration of the telephone plate. This reading was not used in the final estimate of the intensity of the sound, but merely as a preliminary guide.

The sound used for producing the rhythm was that made by a telephone receiver, through which passed an alternating current of 60 alternations per second (a branch from the city lighting circuit), which current, in turn, was interrupted 250 times per second by a tuning fork. The object in having the current interrupted by a tuning fork was to get rid of a click which otherwise occurred at the moment of breaking the current. It was found that, if a current which produced an approximately pure tone was used, there was a very slight click, both at the instant of making the circuit and of breaking it, especially, however, at the break. One could not be sure in judging by the ear alone that this click was not an illusion due to contrast with the preceding or following silence; but Professor Pillsbury succeeded in demonstrating its



existence objectively through the aid of a string galvanometer set up in circuit with a microphone placed in front of the telephone. I tried many methods of eliminating this click, suggested by officers of the departments of physics and of electrical engineering, but they all failed. Finally, I noticed that in some experiments in which I was using an induction coil in order to get a telephone sound, there was no click at the break and make. As the ordinary inductorium is not absolutely reliable as regards the regularity

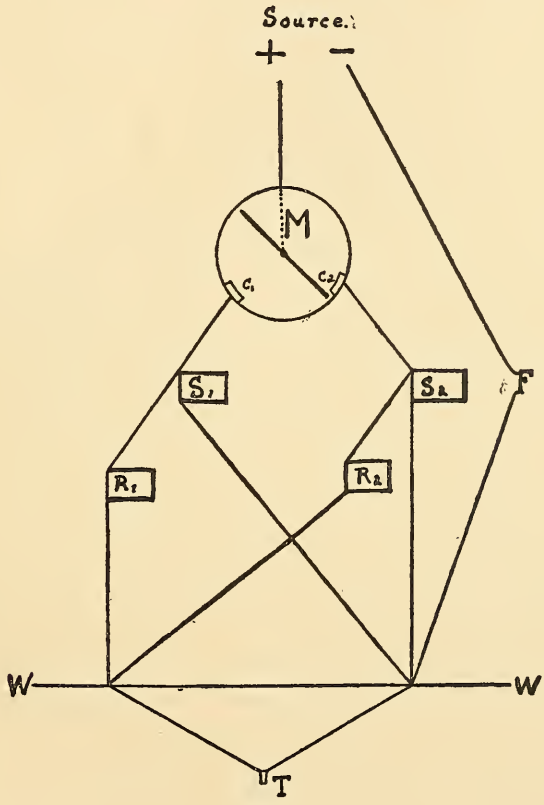


Fig. 1

M = Meumann's machine.
c_1c_2 = contacts.
S_1S_2 = adjustable shunt resistances.
R_1R_2 = adjustable resistances.
WW = wall.
T = telephone.
F = 250 fork.

of vibration and resistance of its interrupter, at the suggestion of Dr. Shepard, a tuning fork with a vibration frequency of 250 per

second was substituted. The platinum plate of the fork was provided with a specially devised micrometer screw arrangement, which made it possible accurately to control the closeness of the contact. Needless to say, this contact, as well as all others, were kept bright as new throughout the investigation and frequently renewed. The sound produced in this manner, according to all the subjects who took part in the investigation, was perfectly even and uniform, and was absolutely free from a click at either the beginning or ending.

For the purpose of making and interrupting the sounds, a Meumann's time-sense apparatus[1] was used, on which were arranged ordinarily from 2 to 6 contacts. Each contact, at the time it was closed, formed part of a separate circuit. By changing the amount of resistance in these separate circuits, the intensity of any sound could be varied independently of that of any other. This arrangement is shown in the diagram on the preceding page.

Whenever any measurements of intensity were made, all the contacts and all circuits were arranged as in actual use. This was necessary inasmuch as part of each circuit constituted a shunt for the other circuits.

As a measure of the intensity of the sounds, the distance to which they were just audible was taken. It is not claimed that such a method of measurement is very exact, but on the whole it was considered the most satisfactory. The measurements were all made on the same day, Sunday, during the summer vacation, about two weeks before the opening of college, in Ann Arbor, in an open space on the campus left by the removal of an old building. Only a few series of measurements were taken for each sound, as Sunday was the only day it was quiet enough to work, and it was found impossible in the course of about two months to get more than one good Sunday, that is, one which was free from wind or rain, or the noise of birds, crickets, etc. I obtained as many series of measurements as was possible in one day, working from early in the morning until after dark, with Mr. Dockeray, at the time assistant in psychology in the University of Michigan laboratory. Environmental conditions were constant throughout the day. The method of minimal changes was used, and from 2 to 6 series were obtained with each intensity. At each step, the sound was presented three times in succession, each time for about 1 second. The operator gave the subject a signal by waving a handkerchief a short but variable time before the first sound, and the subject indicated his judgment by raising a handkerchief whenever he thought he heard the sounds

[1] *Phil. Stud.*, 12, 142–152, 1896

and keeping it lowered the rest of the time. The intervals between the three successive presentations of the sounds were made quite irregular. If the subject signaled at such times as to indicate that he heard all three sounds or two out of three, he was considered to have judged "sound audible;" if he signaled correctly for only one of the three sounds, his judgment was called "doubtful;" if he got none right, he was marked as if he had judged "sound inaudible." The method used was therefore really a combination of the method of minimal changes and the method of constant stimuli.

The following measurements were made of the sounds used in this investigation, the distances being given in feet:

Distance audible	No. of series	M. V. (absolute)
24	6	1.2
28	2	1.0
30	2	0.8
32	4	2.6
40	2	2.0
70	3	1.2
136	3	4.3
196	2	6.0
300	4	24.6
420	4	17.3
616	2	35.0
800	4	56.0
1100	2	50.0

In the remainder of this work, whenever the intensity of a sound is indicated, what is meant is the distance to which it was audible.

The rate of rotation of the Meumann's apparatus, and so the rate of succession of the sounds, was controlled by a Helmholtz motor and two ball-bearing speed-reducers. The rate of rotation of the Helmholtz motor was kept as constant as possible through the aid of a speed counter and stop watch, and an adjustable resistance in the circuit passing through the motor. An accurate record of the rate of rotation as well as the duration of each sound and each interval could be obtained by placing in the same circuit with the telephone a time marker writing on a drum alongside another time marker of 100 single vibrations per second. It was, of course, out of the question to measure individually every one of the sounds and intervals used, as the total number was over half a million. What was done was to take several drums of records of each different rhythm used, both at the beginning and end of the hour, and to keep testing the rate of revolution of the time-sense apparatus by a stop-watch and speed counter during the

hour. How great a degree of regularity of speed was obtained is indicated by the mean variation of the following measurements of the times of successive revolutions:

Duration of 1 revolution	N.	M. V. per cent.
1.50 secs.	50	0.3
3.00 secs.	56	0.5

A part of this variation is, of course, due to inaccuracies in estimating fractions of a vibration of the fork. I will show later (Chap. IV) that my results would not be changed even by very considerable variations in the rate of revolution. Such extremely small mean variations in the rate of revolution as those just indicated have, therefore, no significance for the results of this investigation, and for that reason, in the tables to follow, no mention is made of the mean variation in the rate of revolution of the time-sense apparatus. Changes in the rate were made by the aid of the speed-reducers. A range of rate was obtained from one revolution in 0.5 seconds to one revolution in 26.0 seconds.

When variations in the duration of the sounds were desired, contacts of different length were used. The accurate measurement of the duration of the sounds was accomplished in the manner described above. Finally, it was possible, within certain limits, to arrange for any desired combination of intensity and duration in the sounds composing the rhythmical series.

Given a series of sounds which may be varied in intensity and duration, the question arises, how are we to investigate the effect of these variations? The question to be solved is, what values have intensity and duration for the impression of rhythm which is obtained in listening to the series of sounds? If the study is to take on a quantitative aspect, there must be some measure of the magnitude of the rhythmical attribute of the total impression; there must be some index to show us whether more or less rhythm is felt, some way of telling which of two rhythms, both of which may perhaps be qualitatively alike, in the sense that they are both trochaic or both iambic, is the stronger or more emphatic. The members of a group may be thought of as being held together more or less securely, by stronger or weaker bonds; and what we desire is a measure of the force with which these members of a group are held together—a measure of what McDougall calls "the rhythmic integration of the stimuli."

A very direct method would be to ask the subject to introspect regarding the relative amount of rhythm produced by two different series of sounds. This task is similar to that required of subjects

in experiments on the so-called intensity of sensation. The introspection in the case of rhythm, however, is more difficult, and I doubt if reliable results can be obtained from an investigation carried out in this way. For instance, suppose we compare two trochaic rhythms, one produced by an alternation in intensity and one by an alternation in duration. It may be very apparent that both rhythms are what we call trochaic, but the total impression is very different in the two cases, and it is very hard to isolate the intensive aspect; and consequently it is difficult to say in which case the rhythm is the stronger; and it would be still more difficult to say which is the stronger if one were trochaic and the other iambic. I found that such judgments were not impossible, but I have preferred a more indirect and more objective method, one that demands something far less difficult on the part of the subject.

The following description of the method used in this research may be found rather difficult to follow by those who are unaccustomed to the terminology of rhythm; but I believe that, if the reader will take a pencil and paper and follow out by the aid of symbols the procedure below outlined, he will find no ambiguities. It should be remembered that in all the rhythms here dealt with every second or every third sound is either louder or longer than the others. Also that rhythm is characterized by an apprehension of the sounds in groups and that when there is no grouping there is no rhythm. The method consists in taking as the measure of the amount of rhythm the amount by which, measuring from the point at which all intervals are equal, the internal intervals, or intervals within the group, must be increased or decreased with respect to the external intervals, or the intervals between the groups, in order to cause a disappearance of the rhythm, that is, a disappearance of apparent grouping. Roughly speaking, I have used as the measure of the amount of rhythm the amount of work that had to be done on the intervals to destroy the rhythm. Suppose, for instance, that a certain series of sounds in which every other one is accented, produces an impression of trochaic rhythm, the accented sound seeming to begin the group. Now, such a rhythm can be changed to an iambic one by increasing the interval following the accented sound, with respect to the interval preceding the accented sound. I have found no exception to this possibility. Moreover, as the process of increasing the interval after the accented sound is going on, just before the rhythm becomes iambic, there will be a point reached at which the rhythm can hardly be said to be more iambic than it is trochaic. This point may be called the iambic-trochaic indifference point. It is the point at which

the rhythm is destroyed, or at least reduced to a minimum. If, to arrive at this point, it was necessary to produce only a very slight increase in the duration of the interval after the louder sound with respect to the duration of the interval before it, the rhythm may be said to have possessed only a slight degree of temporal segregration to begin with; and that slight degree of temporal segregation to have been in the trochaic direction. This means that, to begin with, the temporal grouping of the sounds was such that the sounds within the same group were only slightly more grouped than two successive sounds belonging to different groups.

Now, if it is desired to determine the effect of intensity or duration on temporal segregation, we must be able to separate the influence toward temporal segregation exerted by intensity and duration from that exerted directly by unequal temporal spacing of the sounds. The temporal segregation we wish to measure is, of course, the apparent, or subjective, temporal segregation—the temporal segregation presented by the rhythm consciousness and not that presented by the objective series. If the indifference point occurs where the intervals are objectively equal, then any differences in duration or intensity which may exist in the sound series are evidently exerting no influence towards temporal segregation. To measure the amount of temporal segregation produced by changes in intensity or duration we must determine the amount of change in the intervals, *from objective equality*, necessary to arrive at the indifference point, or, what amounts to the same thing, take as the measure of the temporal segregation produced by intensity or duration the difference at the rhythm indifference point between the intervals before and after the accented or the longer sound. If, when the intervals are equal and every other sound accented, the rhythm is heard as trochaic, but if this trochaism[1] can be destroyed by increasing the interval after the accented sound, then it is clear that the accent is exerting some influence toward temporal segregation in the trochaic direction. Moreover, if in one case the interval after the accented sound has to be increased 10 per cent., starting with intervals equal, and in a second only 1 per cent., in order to arrive at the point of indifference, it is clear that a greater degree of temporal segregation in the trochaic direction exists in the first case than in the second. On the other hand, if, with equal intervals, a series of sounds should produce the impression of iambic rhythm, but this impression is changed to one

[1] This word was suggested to me by Professor Titchener as at least preferable to "trochaicness."

of indifference by increasing by 10 per cent. the interval *before* the accented sound, then this rhythm could be said to present the same amount of temporal segregation as the series which, with equal intervals, produced the impression of trochaic rhythm, but in which an increase of 10 per cent. in the interval *after* the accented sound brought the listener to the indifference point. Both rhythms could be said to present the same degree of temporal segregation; but one would be in the iambic direction and the other in the trochaic. The influence towards temporal segregation exerted by any such factor as recurrent differences in accent, pitch, duration, etc., may, therefore, be measured by the difference between the external and internal intervals of the group at the indifference point. In the tables of the following chapters this difference has been recorded in the columns headed A–B, which means the difference in duration at the rhythm indifference point between the interval after the accented or the longer second (A) and the interval before the accented or longer sound (B). When A–B is positive, this means that the series is heard as trochaic, when negative, as iambic, providing the intervals are objectively equal. Further, the magnitude of A–B, when positive, is a measure of the degree of temporal segregation in the trochaic sense; when negative, of the degree of temporal segregation in the iambic sense—so far as this segregation or grouping is due to other factors than objective difference of intervals.

But is measuring the amount of temporal segregation the equivalent of measuring the amount of rhythm, the amount of trochaism or iambism? I shall show, in Chapter VI, that rhythmical grouping is a temporal grouping. Rhythmical segregation implies (subjective) temporal segregation. Then "more" or "less" applied to rhythm means more or less temporal segregation; and, in measuring the amount of temporal segregation, we obtain an index of the quantity of rhythm. This same conclusion may be reached by a different line of reasoning. The judgments, iambic, trochaic and doubtful, have a certain range of distribution. If we admit that a rhythm which is judged trochaic 95 per cent. of the judgments is more trochaic than one which is judged trochaic in 60 per cent. of the judgments, then we must also admit that our measure of temporal segregation serves also as a measure of more or less rhythm: because as the degree of temporal segregation in the trochaic direction exerted by an alternation of more and less intense sounds increases (because of increase in the ratio between the intensities) the percentage of judgments "trochaic" also increases, the objective intervals remaining equal. In other words, to destroy a trochaic

group which is strongly enough trochaic to be judged trochaic in 95 per cent. of the trials, a larger increase in the interval after the emphasized sound is necessary than that required to destroy a trochaic group which is only strong enough to be judged trochaic in 60 per cent. of the trials. We may conclude, then, that the magnitude of A–B, when positive, may be taken as a measure of the degree of trochaism, when negative, of the degree of iambism, in so far as this trochaism or iambism is due to other factors than objective differences in the intervals between the stimuli.

No use has as yet ever been made of this rhythm indifference point. McDougall, as I have already explained, made use of the indifference point in the estimation of time intervals. The question asked of his subjects "was invariably as to the apparent relative duration of the two intervals,"[1] and the indifference point at which he arrived represents "the quantitative proportion of the two durations necessary to produce the impression of temporal uniformity in the series."[2] The subjects who took part in the present investigation, however, were instructed, except in certain cases mentioned later, first, to judge whether the sounds produced an impression which they would speak of as rhythmical, and second, in case there was rhythm, to indicate as best they could the nature of the rhythm. In their judgment as to the quality of the rhythm, they usually made use of the terms iambic, trochaic, etc.; but as full an introspection as the subject was able to make was taken on every rhythm to which he listened. Nothing was said to the subjects about duration of intervals or temporal uniformity. The indifference point here means a point at which the rhythm is no more one type than another. The iambic-trochaic indifference point is the point at which the impression is no more trochaic than iambic, but at which a slight increase in the interval following the accented sound causes the impression to become one of iambic rhythm, and a slight decrease in the same interval changes the impression to that of trochaic rhythm. That such an indifference point is also the indifference point for the perception of the time intervals is by no means self-evident, and the question can be settled only by experiment. I shall show[3] that the two indifference points correspond very closely indeed, but are not quite identical.

I have defined the indifference point as regards rhythm as that point at which the impression is no more that of one rhythm than of another, *i. e.*, the point at which one rhythm is just as natural and

[1] *Monog. Sup. Psychol. Rev.*, 4, 379, 1903.
[2] *Ibid.*, p. 378.
[3] Chap. VI.

just as easy as another, instead of defining it as the point where no rhythm at all exists, because rhythm may occur even at the indifference point. As Professor Woodworth has pointed out, the same series may be heard in different rhythms.[1] The following introspections from subjects who have had a great deal of experience with rhythms near the indifference point are very definite. Subject Ws. writes: "At the very point where iambic turns trochaic, there seems to be no rhythm at all. The reason I put down 'doubtful' is because I can determine no rhythm. If I could determine rhythm, I could tell whether it was iambic or trochaic. At the turning point, there is just a series of sounds, one louder than the other. It seems to me that at one point there is formed a continuous, even, undivided series, and no rhythm exists. At this point,you can make the rhythm either iambic or trochaic, in your mind." Subject Ww. says: "My general conclusion concerning the indifference point is that I can get any one of three things—no rhythm at all, iambic, or trochaic—any of the three cases may occur depending upon the way I attend to the sounds—the way I listen to them." Subject Br, who always counted when he obtained the rhythmical effect, except in cases where he purposely avoided it, gives the following introspection: "At the time when the notes and intervals were all equal, the idea of number, that is, the impulse to count one, two, dropped out. An idea of mere succession remained." These introspections seem sufficient to establish the fact, that, at the indifference point, rhythm may entirely disappear, but also that either one of two rhythms may be obtained with about equal facility.

Notwithstanding the fact that the impression of rhythm produced by a series of sounds depends to a large extent upon subjective factors, it is none the less true that it depends largely on the nature of the sound series, and it is by no means impossible to study the relation between the series of stimuli and the ensuing impression. When the series of sounds is not near the indifference point, the rhythm perceived by any one subject as the result of any given series of stimuli is practically always the same. And if the subjects are instructed in all cases to indicate which rhythm is the most natural or the easiest, it will be found that the indifference point is really a quite narrow zone, though of course a variable quantity. I instructed the subjects in this manner; and throughout the following work, whenever it is indicated that a certain series of sounds produced a certain impression of rhythm, it is not meant that any other rhythm was absolutely impossible, but that the subject found the rhythm indicated to be the most natural. To indicate the

[1] *J. of Phil. Psych. and Sci. Meth.*, 4, 17, 1907.

manner in which the instructions were followed I cite the following introspection from Ws: "Each time, before determining whether the rhythm is iambic or trochaic, I try it each way. When the loudest and longest note comes first, I put down trochaic; but when it comes at the end of each rhythm, I put down iambic. When I can not distinguish any definite rhythm or tell which comes first, the loud or the soft tone, I put down uncertain. It is not like an impression which comes immediately but which comes after listening a while. I do not notice the length of intervals especially." Subject Wr writes that "Possibly the judgment iambic or trochaic does not mean always that this is obtained the easiest, using easiest in the sense of least effort, but perhaps it has occasionally meant merely most satisfying." All subjects reported that there was no difficulty in following the instructions. Whenever they were not sure of the rhythm, they indicated the fact.

The method used to arrive at the indifference point was the method of minimal changes. The subject was first presented a series of sounds concerning the rhythmical nature of which there was no doubt, a series concerning which he could judge "plainly iambic," or, "plainly trochaic," etc. The time allowed for this judgment in the early part of the investigation was 45 seconds, *i. e.*, the rhythm was allowed to run along unchanged for 45 seconds. In the greater part of the work, however, the rhythm was continued until the subject made up his mind, which event was indicated to the operator by an electric bell signal. In case the subject had not made up his mind, however, at the end of one minute, the rhythm was stopped anyway, and the subject, in these cases, wrote "doubtful." If the judgment "doubtful" occurred on the first rhythm of the series, this judgment was thrown out and the series commenced at some other point where the judgment was that the rhythm was plainly one thing or another. The theory of the method of minimal changes seems to require that we take as our starting-point some point where the judgment is not in doubt. The judgment "doubtful" on the first member of the series occurred very seldom, not over twenty times in the whole investigation; and most of these cases occurred in the presentation of the first series or two of a new rhythm, before the operator had any definite idea as to where the indifference point was located, or, consequently, where best to start the series. The very few remaining judgments of doubtful on the first member of the series occurred in cases where the series was started nearer than usual to the indifference point, either in the hope of hurrying the progress of the investigation or of preventing fatigue on the part of the subject.

In case the first judgment was "trochaic," the interval following the more intense or the longer sound was slightly lengthened, and that preceding shortened by the same amount. This second rhythm was then given for 45 seconds, or until the subject had made up his mind. This procedure was continued until the subject judged "plainly iambic." This whole series was then repeated many times either in the same or reverse direction. In case the first judgment was "iambic," then naturally the succeeding rhythms of that series were produced by shortening the interval following the louder or longer sound and lengthening the interval following the weaker or shorter sound. Similarly, to pass from dactylic rhythm to anapaestic, the interval following the emphasized sound was increased while the others were decreased. The number of rhythms, *i. e.*, the number of steps, in any one series, varied from four to fifteen, but was usually between five and nine. The subjects knew that the change from one rhythm to another was effected by changing the intervals, and that the direction of this change was such that the rhythm would finally go over to something else. They were ignorant of the starting point and the size of the steps. They were informed that the size of the steps might vary considerably or might not vary at all. As a matter of fact, their size varied in different series from .02 to .06 second, in the case of rhythmical measures the total duration of which was 1.5 seconds, and correspondingly for longer or shorter groups. This means that in rhythmical groups the total duration of which was 1.5 seconds the same interval in any two successively presented rhythms of the same series would vary only by from .01 to .03 second, inasmuch as one interval was lengthened as the other was shortened. The most usual variation between any two consecutive steps was .016 second. Very often the subject could notice absolutely no difference in two successive rhythms. I believe that, under the conditions of this investigation, the size of the steps was usually about what would correspond to a just noticeable difference. For any one series of minimal changes, the steps were the same throughout.

It is quite conceivable that under some conditions the judgment concerning rhythm might be strongly influenced by which sound was heard first. There exists, *e. g.*, a tendency, under certain conditions, for persons to hear a series of sounds as trochaic in case the louder note first reaches the ear, though the same series is judged iambic in case the weaker note is the first to reach the ear, or, as I believe may be said with greater truth, the first to receive attention. There can be no doubt of this tendency. I remember that, at the beginning of this investigation, I was rather surprised to hear a

subject judge a rhythm to be trochaic which I had judged to be plainly iambic; but, on listening a second time to the same series, I, too, got the impression of trochaic rhythm; and I soon found that which I got depended on which note I heard first. I think it probable that this effect is due to the fact that a certain direction of attention is prescribed by the way the rhythm starts out, inasmuch as this same shifting of the rhythm may occur within one and the same series by shifting the direction of attention, at least according to the introspection of all the subjects I have questioned on this point. The instructions given to my subjects prevented this influence, of the way the rhythm starts out, from affecting my results. Inasmuch as the subjects were to judge which rhythm was the more natural, in those cases in which there could possibly be any doubt concerning the rhythm, and, with some subjects, in every case (as introspections quoted above show), the subjects tried both rhythms to see which was the more natural. Hence it would not matter which way the rhythm started. I have proved that this is the case by keeping throughout quite a period a record of which sound began the rhythmical series. The following table proves that it did not matter for the purpose of this investigation which sound began the series. The table represents the readings in degrees, on Meumann's machine, of the movable contact, at the rhythm indifference point, first, using series in which the longer sound was given first in each case, and second, using series in which the rhythms were always begun on the shorter sound. The temporal value of 1 degree during this work was .00833 second. N refers to the number of series of minimal changes.

Subject	Longer sound given 1st.	N.	Shorter sound given 1st.	N.
Ws	102.5	10	102.5	11
	106.8	9	106.3	11
	110.8	9	112.1	16
	122.9	15	121.3	14
	111.9	4	111.4	7
	84.6	17	85.0	16
	101.5	17	102.0	11
	97.1	6	95.8	5
	97.0	5	96.0	4
	73.3	14	75.0	14
	111.3	14	111.7	13
	107.5	14	107.5	14
Py	105.0	11	114.0	16
	113.8	14	103.4	15
	102.0	6	102.0	6
Wr	102.5	10	102.5	11
	101.0	8	103.4	7
	86.0	16	83.1	6

Notwithstanding that the above results show that, under the conditions of this research, the results were not affected in any very appreciable degree by the question as to which sound came first, nevertheless the precaution was taken throughout to begin about equally often with each note, both in the case of two-membered and three-membered rhythms.

While the method of minimal changes has been used almost exclusively in this research, I have also occasionally used a method of constant stimuli, and cite below results on the same point by the two methods. Both methods, of course, have advantages and disadvantages, but for the purpose of this research no other method than that of minimal changes could even be seriously considered, because of the greater time required, and it would have been absolutely impossible to get any of the subjects to work another hour longer than they did. As it was, three of the subjects, Ws, Dy, and Ww, served for over 300 hours each. From the experiments I performed with the method of constant stimuli, I estimate that 50 per cent. more time would have been required to cover the same ground; and, as far as I can see, the results, even then, would have been less reliable.

It may be well to point out that, while I have spoken of the method used as that of minimal changes, there was no standard stimulus with which a changeable one was compared, and that consequently the procedure is different from that of the method of minimal changes as ordinarily described. The act required of the subject was merely one of introspective description of a single stimulus, the stimulus consisting of a series of sounds. To a certain extent, the judgment was a matter of identification. Further, it may be well to repeat in this connection that the same objective rhythm continued for about 45 seconds, during which time, of course, a large number, say about 30, separate rhythmical groups were presented. The judgment of the subject occasionally underwent several fluctuations before a final decision was reached. Several different and more or less opposed judgments might be made during the continuance of the same rhythmical stimulus; but, unless one of these seemed much less forced than the others, such rhythms were judged "doubtful."

The middle point of this doubtful zone is what is given as the indifference point. In most series, the doubtful zone was quite small. In many series, it was less than the size of the steps used in changing the rhythm. Thus the judgment "iambic" would be given up to a certain point and then a sudden change on the very next step to "trochaic" would occur. In these cases, the indifference point

is considered as lying halfway between the last "iambic" and the first "trochaic" judgment. The treatment of series in which the judgments do not follow a regular course has always been a matter for difference of opinion. Some authors advocate considering all judgments as "doubtful" between those judgments which are alike for three successive judgments, while others advocate neglect of all return to the judgment "doubtful" or to the judgment which began the series after one sure judgment has been made which is different from the sure judgment which began the series. Both procedures are plainly unjustifiable theoretically. The question might possibly be settled on an empirical basis, but never has been. The method I have used for treating such series, while one that has never been rigidly advocated, I believe to be the only one that does not lead to absurdities. The method used consists in shifting the doubtful and reverse judgments all to the middle before taking the average. In part, this procedure follows conventional usage. Thus, the rhythm indifference point in the following series would, by most persons, I presume, be considered as lying between numbers 5 and 6, *i. e.*, half way between numbers 3 and 8.

Place in series	Judgment
1	iambic
2	iambic
3	iambic
4	trochaic
5	iambic
6	trochaic
7	iambic
8	trochaic
9	trochaic
10	trochaic

We should get the same result if we shifted judgments 4, 5, 6, and 7 in such a way that all the iambic lay together and all the trochaic together, *i. e.*, changed the places of the trochaic judgments 4 and 6 with the iambic judgments 5 and 7. For the sake of consistency, then, any series of judgments should be treated in the same manner. The following two cases will serve as illustrations.

Place in series	Judgment
1	iambic
2	iambic
3	iambic
4	doubtful
5	iambic
6	trochaic
7	trochaic
8	trochaic

Indifference point in above series is at 5.

Place in series	Judgment
1	iambic
2	iambic
3	iambic
4	trochaic
5	iambic
6	trochaic
7	trochaic
8	doubtful
9	trochaic
10	trochaic
11	trochaic

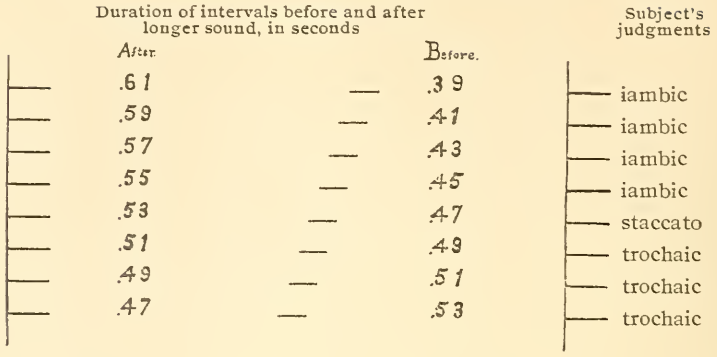
Indifference point in above series is at 5.

In order to save time and prevent fatigue, I told all subjects to consider the series ended when they had obtained two judgments in succession different from the beginning judgment. As a matter of fact, the results of this research would hardly be noticeably affected by the method used in calculating the indifference point as long as any recognized method was followed. But I consider it advisable to have some one definite rule at the start which gives a reasonable result in any conceivable case.

I have not considered it worth while to give in the tables which follow the range of the zone of doubtful cases. Nor have I tried to work out the correlation between the size of any hypothetically defined doubtful zone and the mean variation of the indifference point in successive series. Inasmuch, however, as neither the method of minimal changes nor that of constant stimuli has ever before been systematically applied to the direct investigation of rhythm, that is, to investigations in which the judgment rendered by the subject is a designation of the nature of the rhythm he gets, it may be worth while, in order to give some general idea of the distribution of judgments, to cite the following records selected as typical:

Method of minimal changes. Subject, Py. Rhythmical stimuli consisting of an alternation of two sounds of unequal, but constant, length, and of equal intensity. Longer sound = .09 second, shorter = .06 second. In the column headed "after," is indicated the duration of the interval after the longer sound; in that headed "before," the duration of the interval before the longer sound.

The table below represents the results for only one series of minimal changes. The total number of series of minimal changes used in this investigation was about 24,000. The indifference point in this series is taken as the point at which the interval after the longer sound is .53 second.



The distribution of judgments, as well as the relation between the methods of minimal changes and constant stimuli, is indicated in the following results from subject Ws. The rhythmical stimulus consisted of an alternation of a loud with a soft sound. Loud sound audible to a distance of 136 feet, soft sound audible to a distance of 24 feet. Both sounds 0.13 second in duration. Total duration of one measure, that is, from the beginning of one loud sound to the beginning of the following loud sound = 1.5 seconds. The method of constant stimuli used consisted merely in giving the same objective rhythms as in the method of minimal changes, but in irregular order.

Method of constant stimuli.

Intervals before and after louder sound, in seconds		Subject's judgments (per cent)			
Before	After	Trochaic	Doubtful	Iambic	N
.66	.57	100.0	0.0	0.0	26
.62	.62	85.7	14.3	0.0	42
.59	.64	71.4	28.6	0.0	56
.57	.66	31.3	59.4	9.3	64
.55	.68	0.0	16.0	84.0	50
.53	.70	0.0	5.5	94.5	54
.49	.74	0.0	0.0	100.0	36

Judging from the above table, the rhythm indifference point is about at the point where the interval before the louder sound is .57 second and that following it .66 second. It will be observed, also, that a change by one step from this point is sufficient to make the judgment in over 70 per cent. of the cases either iambic or trochaic depending upon the direction of the change. Moreover, in this case, as in others with the same and other subjects, the results obtained by this method agree very closely with those obtained by the method of minimal changes. Thus, in the present instance,

the indifference point for the same rhythmical series of sounds on the same morning, by the same subject, was found, as the result of ten series of minimal changes, to be at that setting which gives as the interval before the louder sound .57 second (absolute M. V. = .01 second) and that following it .66 second (absolute M. V. = .01 second)—the same result as with the method of constant stimuli.

CHAPTER III

Intensity

The method used for the investigation of the effect of intensity in rhythm consists in finding the indifference point for rhythm with different ratios of intensity between the sounds. The method of determining the indifference point and the method of measuring the intensity of the sounds have been described in Chapter II. Rhythms in which every alternate sound is objectively accented were the ones given most attention. At the rate at which these were usually given, one sound every .75 second, all the subjects invariably got a two-group. Enough work was done on three-membered groups, however, to show that the same general laws hold in both cases.

In the experiments represented in table I., the duration of all the sounds was kept constant and was .13 second, while the total duration of one measure, that is, the time from the beginning of one louder sound to the beginning of the following louder sound, was also kept constant at 1.5 seconds. There were just two different intensities of sounds used in any one rhythmical series, every second sound being louder; and all the louder were of one intensity, and all the weaker of the other intensity. The intensity of the sounds is indicated by the distance, in feet, to which they were just audible. For all the tables presented in this chapter, the weaker sound was just audible at 24 feet. In the column headed A–B, is indicated the duration, at the indifference point for rhythm, of the interval following the louder sound minus the duration of the interval preceding the louder sound. By "before" is meant the interval of silence before the louder sound, *i. e.*, the time from the end of the preceding sound to the beginning of the louder sound; by "after" is meant the interval of silence following the louder sound, *i. e.*, the time from the end of the louder sound to the beginning of the following sound. The quantity A–B, therefore, is obtained by subtracting the corresponding quantity in the column "before" from that in the column "after." N refers to the number of series of minimal changes run through in the determination of any one indifference point. The mean variation (MV) is the mean variation in the duration of the intervals at the indifference point. All the results obtained with any one ratio of intensities are treated as one group in obtaining the mean variation. Inasmuch as one interval was lengthened as the other was shortened, and *vice versa*, the absolute M. V. of one interval is also that of the other; and for that reason, I have given

the absolute M. V. rather than the relative. By "louder sound," is meant the distance to which the louder sound was just audible. All durations are given in seconds.

TABLE I

Effect of Relative Intensity on the Iambic-trochaic Indifference Point. Weaker sound just audible at 24 feet.

Subject	Louder sound	Before	After	N	*MV*	A — B
Wr	30	.613	.617	10	*.008*	.004
	32	.603	.627	9	*.005*	.024
	40	.576	.654	9	*.008*	.078
	70	.567	.663	31	*.025*	.096
	136	.555	.675	10	*.010*	.120
	196	.548	.682	15	*.016*	.134
	300	.547	.683	10	*.012*	.136
	420	.536	.694	25	*.024*	.158
	616	.513	.717	11	*.013*	.204
	1100	.509	.721	17	*.016*	.212
Dy	28	.592	.638	6	*.012*	.046
	30	.573	.657	11	*.012*	.084
	32	.564	.666	11	*.014*	.102
	40	.532	.698	18	*.020*	.166
	70	.532	.698	33	*.023*	.166
	136	.506	.724	15	*.016*	.218
	196	.503	.727	23	*.024*	.224
	300	.499	.731	28	*.023*	.232
	420	.503	.727	10	*.014*	.224
	616	.484	.746	22	*.019*	.262
	800	.456	.774	15	*.022*	.318
	1100	.457	.773	34	*.024*	.316
Ww	28	.594	.636	22	*.022*	.042
	30	.581	.648	28	*.016*	.068
	32	.573	.657	20	*.019*	.084
	40	.568	.662	19	*.026*	.094
	70	.558	.672	23	*.024*	.114
	136	.554	.676	25	*.015*	.122
	196	.546	.684	21	*.022*	.138
	300	.546	.684	21	*.020*	.138
	616	.534	.696	21	*.028*	.162
	1100	.534	.696	20	*.016*	.162
Ws	28	.614	.616	20	*.022*	.002
	30	.600	.630	20	*.009*	.030
	32	.590	.640	20	*.012*	.050
	40	.582	.648	38	*.019*	.066
	70	.577	.653	20	*.021*	.076
	136	.568	.662	58	*.033*	.094
	196	.568	.662	56	*.025*	.094
	300	.566	.664	41	*.021*	.098
	420	.559	.671	44	*.028*	.112
	616	.558	.672	46	*.028*	.114
	800	.563	.667	35	*.019*	.104
	1100	.550	.680	38	*.018*	.130

From the preceding table, it is obvious that with equal intervals and every second sound accented the rhythm is trochaic, that is, the effect of accent is to cause the accented sound to appear grouped with the following weaker sound. In chapter II it was shown that when the quantity A–B is positive, its magnitude measures the trochaism of the sound series. It is obvious, therefore, from Table I, that the rhythm becomes more and more trochaic as the ratio between the intensities of the louder and weaker sounds increases. It is further obvious that the trochaism of the series increases at first very rapidly and later very slowly relative to the increase in distance to which the louder sound is just audible, the weaker remaining constant. The same statement can be made concerning the increase in the intensity of a sensation as the energy of the stimulus increases. It is therefore not impossible that the increase in trochaism tends to be proportional to the increase in the ratio of the sensation intensities of the sounds, but not enough is known of the relation between the energy of sound stimuli and the intensity of sensations to make speculation on this point profitable.

That the effect of an objective accent in three-membered groups is similar to that in two-membered groups is shown by Table II, which presents results obtained when every third sound was the more intense. The indifference point for these tables is the dactylic-anapaestic, and was obtained in the same way as in the case of groups of two sounds each, namely, by shortening the interval preceding the more intense sound and at the same time lengthening the interval following it, or *vice versa*. The interval between the two weaker sounds, which were both of the same intensity, (24 feet), was kept constant throughout, and equal to .577 second. As before, the quantities in the column headed A–B represent the duration of the interval following the louder sound minus the duration of the interval preceding it. The duration of all the sounds was .09 second, and the total duration of one measure, that is, the time from the beginning of one louder sound to the beginning of the succeeding louder sound, was 2.0 seconds.

TABLE II

Effect of Relative Intensity on the Anapaestic-dactylic Indifference Point.

Interval between the two weaker sounds (constant) = 0.577 seconds.

Weaker sound just audible at 24 feet.

Subject	Louder sound	Before	After	N	*M V*	A — B
Dy	32	.541	.613	10	*.028*	**.072**
	40	.525	.629	10	*.022*	**.104**
	136	.517	.637	9	*.013*	**.120**
	616	.479	.675	10	*.020*	**.196**

Subject	Louder sound	Before	After	N	*M V*	A—B
Ww	32	.540	.614	10	*.016*	.074
	40	.523	.631	8	*.013*	.108
	136	.499	.655	12	*.016*	.156
	616	.475	.679	15	*.017*	.204

This same law, namely, that the accented stimulus tends more and more strongly to begin the group with increase in the ratio of intensities of the stimuli, was found to hold good of rhythms in which the stimuli were electrical shocks instead of sounds. The same apparatus was used as in the investigation of sound rhythms except that in place of the telephone, which had produced the sounds, was substituted a pair of sponge electrodes, which were tied to motor points of the arms. Subject Dy gave the introspection that the impression of rhythm was "fully as strong in the case of electrical stimulation as in the case of sound." My own introspection is that there is about as much rhythm in one case as the other. Every third stimulus was the stronger and consequently each group consisted of three movement percepts (each shock producing a twitch of the muscles of the arm): and the indifference point obtained was the dactylic-anapaestic. The results for electrical stimulation are presented in Table III. The total duration of one measure is 2.0 seconds, and the duration of each stimulus equals .09 second. The interval between the two weaker shocks, which were both equal in intensity, was kept constant throughout and was equal to .577 second.

TABLE III

Effect of Relative Intensity on Anapaestic-dactylic Indifference Point when Electric Shocks Are Used as Stimuli.

Interval between the two weakest shocks (constant) = 0.577 second.

Subject	Stronger stimulus	Before	After	N	*M V*	A—B
Dy	weak	.566	.588	6	*.022*	.022
	medium	.553	.601	8	*.017*	.048
	very great	.513	.641	8	*.027*	.128
Ww	weak	.567	.587	6	*.014*	.020
	medium	.561	.593	4	*.016*	.032
	very great	.533	.621	6	*.018*	.088

In the work on sound, all subjects frequently remarked on the greater apparent duration of the louder sound. The difference both in loudness and in duration seemed greater when the rhythm was pronounced than when near the indifference point.

CHAPTER IV

Rate and Intensity

It was desired to study here the effect on the rhythmical impression of changes in the rapidity with which the series was run off. These changes are those produced by varying the rate of rotation of the Meumann's time-sense apparatus. The absolute duration of the measure and of all its parts, intervals and sounds, was varied, while all relative durations were kept constant. One method of changing the rate of a series of sounds is to change only the intervals of silence between the sounds. Such a procedure introduces changes in a factor other than rate, namely, the proportion between the duration of the sounds and the duration of the intervals. In the present experiments, the absolute duration of the sounds was varied in direct proportion to the absolute duration of the intervals between the sounds, so that the proportion of sound to silence and the proportion of either sound or silence to the whole measure was kept constant. The intensities of the sounds were also kept constant.

Tables IV to VI show the effect of variation in the rate of rhythmical series in which every second sound is the louder. The subjects perceived the sounds in groups of two except for the measures whose total duration is indicated as .75 second or .5 second. At these last mentioned rates, the sounds were grouped by four, so that as a matter of fact at these two rates the total duration of the groups was twice that indicated in the tables as the duration of the measure; but the time from the beginning of one of the loud sounds to the beginning of the following is indicated as the total duration of the measure, at these rates as in the other cases, for the sake of readier comparison. In the following tables are presented the duration of the intervals at the indifference point. In the column headed "measure" is indicated the duration of the cycle from the beginning, say, of one loud sound to the beginning of the following loud sound. The expressions, N, M V, A–B, before and after, have the same meaning as in the previous chapter. The quantity A–B, however, which represents the amount by which the interval after the accented sound is longer than the interval before it, at the indifference point for rhythm, is expressed in the following tables as a percentage of the duration, at the indifference point, of the interval before the accented sound. All durations are given in seconds.

TABLE IV

The Effect of Rate on the Iambic-trochaic Indifference Point.

Louder sound just audible at 70 feet; weaker, at 24 feet.
Duration of every sound relative to the total duration of one measure = 13 to 150.

Subject	Measure	Before	After	N	*M V*	A — B
Wr	1.0	.38	.44	13	*.008*	15.8
	1.5	.57	.66	14	*.014*	15.8
	2.0	.77	.87	14	*.007*	13.0
	3.0	1.14	1.32	19	*.054*	15.8
	4.0	1.52	1.76	14	*.027*	15.8
	5.5	2.12	2.39	14	*.055*	12.7
	7.5	3.05	3.11	17	*.100*	2.0
Ws	1.0	.39	.44	11	*.006*	12.8
	1.5	.58	.65	11	*.011*	12.1
	2.0	.78	.87	10	*.016*	11.5
	2.5	.97	1.09	8	*.026*	12.4
Dy	0.5	.18	.23	18	*.007*	27.8
	0.75	.29	.34	19	*.008*	17.2
	1.5	.57	.66	11	*.021*	15.8
	2.0	.77	.87	15	*.015*	13.0
	3.0	1.15	1.31	10	*.032*	13.9
	4.0	1.55	1.73	10	*.040*	11.6
	5.5	2.24	2.27	9	*.051*	1.3
	7.0	3.08	3.08	8	*.096*	0.0

TABLE V

The Effect of Rate on the Iambic-trochaic Indifference Point.

Subject, Ww.
Louder sound just audible at 136 feet; weaker, at 24 feet.
Duration of every sound relative to the total duration of one measure = 13 to 150.

Measure	Before	After	N	*M V*	A — B
0.5	.16	.25	12	*.005*	56.3
0.75	.26	.36	10	*.010*	38.5
1.0	.37	.46	10	*.006*	24.3
1.5	.53	.70	8	*.009*	32.1
2.0	.73	.91	11	*.018*	24.7
2.5	.90	1.16	10	*.022*	28.9
3.0	1.06	1.40	12	*.009*	32.1
3.5	1.29	1.58	10	*.021*	22.5
5.0	1.91	2.19	14	*.041*	14.7
7.5	2.97	3.18	6	*.104*	7.1
10.0	4.03	4.17	7	*.083*	3.5

TABLE VI

The Effect of Rate on the Iambic-trochaic Indifference Point.

Subject, Dy.

Louder sound just audible at 136 feet; weaker, at 24 feet.

Duration of louder sound relative to the total duration of one measure = 37 to 150; of weaker = 13 to 150.

Measure	Before	After	N	*M V*	A—B
1.0	.29	.38	16	*.016*	31.0
1.5	.44	.56	16	*.013*	27.3
2.0	.59	.71	16	*.017*	20.3
2.5	.75	.92	18	*.040*	22.7
3.5	1.05	1.28	16	*.047*	21.9
5.0	1.47	1.87	13	*.072*	27.2
7.5	2.30	2.70	16	*.054*	17.4
10.0	3.20	3.47	16	*.106*	8.4

In considering the above tables, it is necessary to bear in mind the significance of the quantities in the columns headed A–B. As I have previously stated, this quantity is a measure of the amount of temporal segregation presented by the group, and accordingly an index to the amount of rhythm got out of the sound series by the subject. We may therefore describe the effect of variations in rate as follows. Within certain limits the degree of temporal segregation presented by the groups remains very nearly constant. With slower rates, the rhythm entirely or almost entirely disappears. The limits within which the degree of temporal segregation remains relatively constant vary with individuals and with the nature of the objective series. Thus, in the case of subject Dy, in the case presented in Table IV, where there was merely a difference in intensity between the sounds, the rhythm dropped off very suddenly between a rate which gave as the total duration of one measure 4.0 seconds and one which gave as the total duration of one measure 5.5 seconds. With a different sound series, however, one in which the louder sound was also the longer (Table VI), a certain amount of rhythm persisted even at a rate which gave as the total duration of one measure 10.0 seconds; though even in this case there was already a very considerable decrease at the rate of 7.5 seconds for one measure. In general, the tables indicate that, from a rate of 1.0 second for one measure up to a rate of between 4.0 and 7.0 seconds for one measure, the degree of rhythm remains about constant.

Sufficient observations have not been made with very fast rates to generalize concerning the effect of increasing the rate beyond 1.0 second for one measure. There is some indication, however, that with rates faster than 1.0 second for one measure there is a marked

increase in the amount of temporal segregation presented by the rhythm. As already stated, grouping by four instead of by two comes in at rates faster than 1.0 second for one measure. Inasmuch as subjective rhythm comes in very markedly at rates of about 1 second for two beats or faster, the increase above noted in the rhythmical effect for the faster rates can hardly be regarded as the effect of an increase in rate *on the rhythmical effect of intensity or duration*. It seems rather that we have in the case of these rates a subjective factor which is more or less independent of any differences which may prevail in the intensity or duration of the sounds composing the series, since at these rates grouping occurs when all the sounds are equal both in intensity and duration.[1]

The rate at which intensity and duration completely fail to exert any influence favoring rhythm is indicated as being somewhat slower than that usually given as the limit of rhythm, being in some cases beyond 10.0 seconds for one measure. While a marked decrease in the amount of rhythm got from a series occurs in the neighborhood of from 4.0 to 7.0 seconds for one measure, the limit at which variations in intensity and duration fail to exert any influence making for temporal segregation is indicated as varying from 7.0 to over 10.0 seconds for one measure. Subject Wr, an experienced introspectionist, told me he got rhythm (when the intervals were not too nearly equal) from a rate which made the total duration of one measure 26.0 seconds. What he meant was that when the intervals were not too nearly equal the sounds seemed grouped by twos, and one sound was louder than the other. Now, grouping is usually held to be one of the chief characteristics of rhythm. Yet Table IV shows for this same subject that, so far as the effect of intensity goes, making one sound stimulus about eight times as energetic as the other failed, practically, to exert any grouping effect when the rate was slow enough to make the total duration of one measure equal to 7.5 seconds. It is evidently impossible to fix the upper (slow) limit of rhythm until we have a definition of rhythm, but by the method I have used it is possible to fix the upper limit at which intensity or duration exert any rhythmical effect in the sense of promoting temporal segregation.

All subjects found the work on the very slow rhythms extremely fatiguing, and it was hardly possible at the slowest rates to run through more than 3 or 4 series of minimal changes at one sitting. Extremely close attention is required at these slow rates to get any rhythm at all.

[1] Meumann, *Phil. Stud.*, **10**, 302, 1894.

CHAPTER V

Duration

In the investigation of the effect on rhythm of variations in the duration of the sounds, I did not find so much agreement between different individuals as in the case of variations in intensity. Individual differences, while quite marked in the case of duration, are yet not so great as to prevent certain generalizations.

The investigation of the effect of duration in rhythm was carried on in the same way as the investigation of the effect of intensity, except that instead of using sounds of different intensity, the intensity of all sounds was kept constant and their duration alone varied. As has already been shown, in the case of two-membered rhythms, if we start out with a trochaic rhythm, in which the louder sound begins the measure, by gradually increasing the interval after the louder sound, we arrive at an iambic rhythm, in which the louder sound ends the measure. I found no exception to the possibility of changing in this manner from trochaic to iambic. Similarly, in the case of rhythm in which we have differences in duration of the sounds but not in intensity, if we start with a trochaic rhythm with the longer sound beginning the measure, by increasing the interval after the longer sound and decreasing the interval before it, we will arrive at an iambic rhythm, with the longer sound second. In this case, the longer sound ordinarily seems to the subject to be accented. I found no exception to the possibility of changing in this manner from trochaic to iambic in the case of any of the subjects that I have worked on, and I have tested thirteen subjects in this way. In the case of one subject however, subject Sh, the *most usual* result was not a change from trochaic to iambic. With a sufficient increase in the interval following the longer sound, the rhythm, instead of changing to iambic, remained trochaic, but a trochaic in which the shorter sound was described as accented. In other words, in the case of this subject the *first* sound of the group was usually accented, irrespective of whether the first sound was the longer or the shorter. While I did not get this result in any other case, three other subjects occasionally stated that they had a tendency to hear a trochaic with the short sound accented instead of an iambic with the long sound accented, when the interval after the longer sound appeared the longer. When the interval *before* the longer sound appeared greater than that following it, the longer sound always seemed accented, that is, in no case was any tendency

found to accent the second sound of a two-membered group, when the second sound was the shorter and of equal intensity with the first.

This result seems to indicate that there are two separable objective factors tending to produce subjective accent, at least in some subjects. There is a tendency to accent the longer sound and also a tendency to accent the sound which seems to begin the group. In some subjects there is no evidence of the latter tendency, and only in one subject out of thirteen, subject Sh, was it as strong as the tendency subjectively to accent the longer sound. Only on the supposition of these two separable tendencies does it seem possible to explain the fact, that, when the longer sound appears to begin the group, it invariably receives an accent, whereas when the longer sound ends the group, it occasionally appears less accented than the shorter sound. In the one case the two factors work together; in the other, in opposition.

The apparent intensity of stimuli which, objectively, differ only in duration, is a point of considerable interest. Miner found in his investigation of rhythm that an increase in the duration of a light was mistaken for an increase in intensity. It is, further, a well-known fact, that, in the case of sound, the apparent loudness of a sound increases with the increase in duration, the objective intensity remaining constant. This increase in apparent loudness occurs at first very rapidly and then slower, as the duration is increased; but the maximum of apparent loudness, for sounds of the objective intensity used in this investigation of duration in rhythm, would hardly be reached before the duration had reached at least one second.[1]

The significance of this fact of increase in apparent intensity with increase in duration is very definitely indicated by the following introspection from subject Wr, on a rhythm in which the longer sound was .25 second and the shorter .13 second, and the rhythm given first with both sounds rather loud and then with both sounds rather weak. "There is no doubt but emphasis goes with length: tendency to accentuate short note practically disappeared with weaker intensity." This tendency to accentuate the short note disappears with weak intensities because, when the sounds are weak, a slight difference in duration is of more significance for their apparent relative loudness than when both are quite loud. The results we have just spoken of above, however, show that the greater apparent intensity of one or the other sound is not due

[1] Kafka, "Uber das Ansteigen der Tonerregung," *Psychol. Stud.*, **2**, 256–292, 1907.

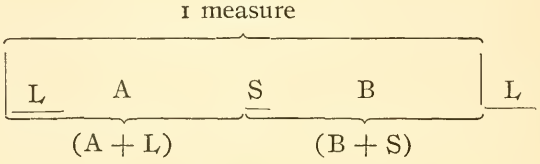
merely to the fact that a sound increases in apparent intensity with increase in duration. In the case of subject Sh, and others, in which the first sound of the group was sometimes accented whether the longer or not, we have an indication that some process in the central nervous system is exerting an effect on the apparent loudness of the sounds. I have also many series of introspections which show that the difference in apparent loudness of the two sounds, when the apparently louder is second, is greater as the interval before the second sound is shortened and the interval before the first or apparently weaker is lengthened. The reverse introspection was never obtained. That is to say, in an iambic rhythm, with the second sound apparently louder than the first, the apparent difference in loudness is often reported as decreasing as the intervals become more and more equal. Similarly in a trochaic rhythm, the first sound often seems to decrease in relative loudness as the intervals are made more nearly apparently equal. These introspections were given by subjects Br, Ww, Py, Dy and Ws. When the intervals were nearly equal, such expressions as "very slight accent," "emphasis exceedingly light," "accent doubtful, depending on will" were obtained, while when the intervals were unequal, such introspections as "accent very pronounced," "2nd (or 1st) clearly louder" etc., were given. Concerning a series in which the sounds were unchanged, but the intervals varied in the usual way, subject Ws writes: "The notes are more nearly of the same length as you approach the changing point" (indifference point). Subject Br, concerning a rhythm in which the longer sound was 0.07 second and the shorter 0.06 second: "The longer notes seem more intense and slightly higher than the shorter. When the intervals are about equal, the length and intensity of the notes also seem about equal. According as the attention seizes on one note or the other, is the position of accent and the grouping determined. *At the time the intervals are equal, difference in length and intensity practically disappears.* The difference became more pronounced whenever the rhythm was more pronounced."

These results show that, in some cases, at least, the greater apparent intensity of one or other of the sounds is due to some central process, a conclusion similar to what seems inevitable in regard to the subjective accent in purely subjective rhythm. I think that this process is probably that of attention, but I do not care to insist on this at present, as it would require too much space to give all the grounds for such a belief. It is some process, however, which is quite separate from that involved in the increase in apparent intensity resulting from an increase in duration.

The general conclusion, then, is that the longer sound should naturally appear the louder, as we might say, for sensory reasons, apart from more complicated or more central processes. At the same time, there is some central process, possibly attention, which has some slight effect on apparent intensity. When the longer sound appears the louder there is no necessity for considering this as due to greater attention directed to the longer. On the contrary, the shorter might be receiving the greater amount of attention and yet not appear as loud as the longer, the physiological or sensory effect exerted by duration on intensity being able to swamp the slight effect of the central process on intensity, in case the two processes work in opposition. In those cases, however, where the shorter sound seems the louder, the central process is evidently having a stronger effect than the sensory. It is possible that all the subjects have not used the words intensity, and accent, and emphasis in the same sense, and that the effects referred to in some cases as differences in intensity were differences in some other sort of emphasis; but this makes it all the more desirable to distinguish between the unquestionable effect on intensity of increase in duration and the effect on something referred to as accent or as intensity, exerted equally unquestionably by some other apparently more central process.

The results obtained with regard to the indifference point in two-membered rhythms produced by alternation of a longer and shorter sound of equal objective intensity and of the same quality are presented in Tables VII and VIII. By the total duration of a measure, or in Table VIII, by "Measure," is meant the time, say, from the beginning of one long sound to the beginning of the next long sound. By N, is meant the number of series of minimal changes run through in the determination of any one indifference point. The tables show the length of the intervals at the indifference point for rhythm. By the interval "before," is meant the duration of the interval before the longer sound, *i. e.*, the time elapsing from the end of the short sound to the beginning of the long; and by the interval "after," is meant the interval after the longer sound, *i. e.*, from the end of the long sound to the beginning of the short. The mean variation referred to is the variation in the length of these intervals. All the results obtained from any one ratio are treated as one group in obtaining the mean variation. Inasmuch as one interval was lengthened as the other was shortened, and *vice versa*, the absolute M V of one interval is also that of the other; and for that reason, I have given the absolute M V rather than the relative. In the column A–B, I have indicated the difference in duration

between the interval following the longer sound and that preceding it. In the column headed (A + L) — (B + S), is indicated the difference between the duration of the interval of silence after the longer sound + that of the longer sound and that of the interval of silence before the longer sound + that of the shorter sound. In other words, in this column the measure is considered as being composed of two intervals each of which extends from the *beginning* of one sound to the *beginning* of the following sound. The column headed (A + L)—(B + S) presents the duration of the interval extending from the beginning of the longer sound to the beginning of the shorter minus the duration of the interval extending from the beginning of the shorter to the beginning of the longer. The following scheme illustrates this method of treating the measure:



All durations are indicated in seconds. By "longer" or "shorter" is meant the duration of the longer or shorter sound.

TABLE VII

The Effect of Relative Duration on the Iambic-trochaic Indifference Point.

Duration of shorter sound (constant) = 0.13 second.
Total duration of measure (constant) = 1.5 seconds.

Subject	Longer sound	Before	After	N	*M V*	A — B	(A+L)—(B+S)
Ws	.16	.58	.63	31	*.014*	+ .05	+ .08
(July '08)	.19	.58	.60	58	*.024*	+ .02	+ .08
	.22	.58	.57	26	*.017*	— .01	+ .09
	.25	.55	.57	28	*.022*	+ .02	+ .13
	.28	.55	.54	24	*.020*	— .01	+ .14
	.31	.55	.51	26	*.010*	— .04	+ .14
	.37	.55	.45	28	*.014*	— .10	+ .14
	.43	.55	.39	27	*.020*	— .16	+ .13
	.48	.54	.35	22	*.010*	— .19	+ .16
	.60	.54	.23	23	*.018*	— .31	+ .16
Ws	.18	.50	.56	32	*.020*	+ .06	+ .11
(July, '07)	.28	.55	.53	18	*.016*	— .02	+ .13
	.34	.54	.48	41	*.030*	— .06	+ .13
	.54	.51	.31	22	*.025*	— .20	+ .21

TABLE VII—(*Continued*)

Subject	Longer sound	Before	After	N	*M V*	A—B	(A+L)—(B+S)
Ww	.16	.57	.64	15	*.016*	+ .07	+ .10
(July, '08)	.19	.57	.61	16	*.015*	+ .04	+ .10
	.22	.57	.58	16	*.023*	+ .01	+ .10
	.25	.54	.58	16	*.015*	+ .04	+ .16
	.28	.54	.55	10	*.014*	+ .01	+ .16
	.31	.53	.54	10	*.019*	+ .01	+ .19
	.37	.51	.49	15	*.016*	— .02	+ .22
	.43	.47	.47	10	*.015*	.00	+ .30
	.48	.43	.46	10	*.024*	+ .03	+ .38
	.60	.40	.37	16	*.013*	— .03	+ .44
	.72	.36	.29	10	*.011*	— .07	+ .52
	.84	.33	.20	10	*.013*	— .13	+ .58
Ww	.18	.56	.62	31	*.025*	+ .06	+ .11
(July, '07)	.26	.52	.58	23	*.036*	+ .06	+ .19
	.34	.50	.52	28	*.030*	+ .02	+ .23
	.42	.48	.46	21	*.034*	— .02	+ .27
	.54	.43	.39	25	*.020*	— .04	+ .36
Dy	.16	.53	.68	42	*.040*	+ .15	+ .18
	.19	.51	.67	35	*.037*	+ .16	+ .22
	.22	.53	.62	33	*.020*	+ .09	+ .18
	.25	.51	.61	45	*.027*	+ .10	+ .22
	.31	.46	.60	33	*.026*	+ .14	+ .32
	.37	.43	.57	37	*.031*	+ .14	+ .38
	.43	.40	.54	35	*.028*	+ .14	+ .44
	.48	.39	.50	28	*.019*	+ .11	+ .46
	.60	.36	.41	25	*.038*	+ .05	+ .52
	.72	.28	.37	18	*.041*	+ .09	+ .68
	.84	.24	.29	15	*.020*	+ .05	+ .76
Wr	.16	.61	.60	15	*.027*	— .01	+ .02
	.19	.58	.60	11	*.011*	+ .02	+ .08
	.22	.58	.57	25	*.020*	— .01	+ .08
	.25	.54	.58	16	*.018*	+ .04	+ .16
	.28	.55	.54	16	*.023*	— .01	+ .14
	.31	.53	.53	17	*.011*	.00	+ .18
	.37	.54	.46	15	*.014*	— .08	+ .18
	.43	.51	.43	17	*.023*	— .08	+ .24
	.48	.49	.40	19	*.014*	— .09	+ .26
	.60	.44	.33	19	*.024*	— .11	+ .36

TABLE VIII

The Effect of Relative Duration on the Iambic-trochaic Indifference Point.

Subject	Measure	Shorter	Longer	Before	After	N	*M V*	A — B	(A + L)—(B + S)
Ws	.64	.05	.06	.24	.30	10	*.017*	+ .06	+ .07
			.07	.22	.30	12	*.018*	+ .08	+ .10
			.08	.23	.29	10	*.012*	+ .06	+ .09
			.10	.21	.27	10	*.020*	+ .06	+ .11
			.15	.22	.22	11	*.019*	.00	+ .10
			.20	.23	.17	11	*.011*	— .06	+ .09
			.25	.22	.12	11	*.018*	— .10	+ .11
Ws	1.11	.10	.13	.39	.49	10	*.017*	+ .10	+ .13
			.15	.39	.47	10	*.016*	+ .08	+ .13
			.16	.38	.46	10	*.019*	+ .08	+ .14
			.20	.38	.44	11	*.016*	+ .06	+ .16
			.23	.38	.40	10	*.015*	+ .02	+ .15
			.25	.37	.39	10	*.015*	+ .02	+ .17
			.29	.38	.34	12	*.017*	— .04	+ .15
			.34	.37	.31	10	*.012*	— .06	+ .18
Py	1.49	.13	.18	.55	.63	32	*.032*	+ .08	+ .11
			.34	.48	.54	26	*.039*	+ .06	+ .29
			.54	.40	.43	32	*.031*	+ .03	+ .45
Vt	1.11	.10	.13	.39	.49	10	*.016*	+ .10	+ .13
			.20	.37	.45	11	*.010*	+ .08	+ .18
			.25	.37	.39	10	*.017*	+ .02	+ .17
Br	1.50	.08	.10	.60	.72	11	*.030*	+ .12	+ .14
			.18	.60	.64	10	*.027*	+ .04	+ .14
			.27	.59	.57	10	*.014*	— .02	+ .17
			.35	.57	.49	10	*.017*	— .08	+ .19
			.43	.58	.40	7	*.017*	— .18	+ .17
			.52	.55	.35	8	*.017*	— .20	+ .24
			.60	.55	.27	8	*.015*	— .28	+ .24

As I have already indicated in Chapter II (pages 17–20), the magnitude of A–B, when positive, may be taken as a measure of the degree of trochaism, when negative of the degree of iambism presented by the group when the intervals between the sounds are objectively equal. A study of the columns headed A–B in the above tables shows that without exception the rhythm becomes less trochaic or more iambic as the ratio between the longer and shorter sounds increases. In some cases, as with subjects Ww, Ws, Wr and Br, the change is one from a trochaic rhythm through an indifference

point to a more and more pronounced iambic. In other cases, as with subjects Py, Dy and Vt, the change is one from a very decided trochaic to a less stable trochaic. In the case of Vt, however, there is little doubt but that the rhythm would have become strongly iambic with larger ratios between the durations of the sounds. In the case of Dy, the change is very slight; but it is still evident enough to render it unnecessary to regard this subject as an exception to the general rule. The general law indicated, then, regarding the effect of the relative duration of the sounds in auditory rhythms, is that the rhythm becomes less trochaic or more iambic as the ratio between the longer and shorter sounds increases. As I have found this law to hold with several different absolute durations of the shorter sound, it seems more or less general, though I am unable to present data concerning its limits.

Subject Sh might prove an exception to this generalization. I was unable to study the subject thoroughly enough to be sure whether he would or not. In his case, I found that, with a ratio of two to one and equal intervals, the rhythm was trochaic with the longer sound accented. When the interval before the longer sound was made considerably shorter than that after it, the rhythm usually changed to a trochaic with the shorter sound accented. I believe, consequently, that in generalizing the effects of duration on rhythm, it is safer to omit the words iambic and trochaic. I would therefore state the law of the effect on auditory rhythms, composed of groups of two sounds each, exerted by changes in the ratio of the durations of the sounds, as follows: With an increase in the ratio between the duration of the longer and shorter sounds, if the intervals between the sounds are objectively equal, there is an increase in the tendency to obtain a rhythm with the longer sound at the end of the group or a decrease in the tendency to obtain a rhythm with the longer sound at the beginning of the group.

It is interesting to note that when the intervals are objectively equal, the series is heard as trochaic rhythm when the difference in the duration of the sounds is sufficiently small. Out of a total of thirteen subjects, only two, Ws and Wr, ever showed any exception to this statement, and even in these cases the prevailing tendency with the smaller ratios is towards trochaic. In every case, with a ratio of durations of approximately 2 to 1 (25 to 13), with equal objective intervals, trochaic rhythm was the result.

The most strongly trochaic rhythms produced by duration changes are those produced by the smallest ratio of durations. It looks as though, were the series continued up to a ratio of one to one, the series would be more trochaic than ever. This is, however,

not the case. When there is no difference at all in duration (nor in accent) the indifference point was found to be almost anywhere, that is, all judgments become doubtful. The strongest trochaic which it is possible to produce by duration changes alone, therefore, is produced when the longer sound is longer, but only very slightly so, than the shorter sound. It may be that the trochaic rhythm of the smaller ratios was due chiefly to the difference in apparent loudness between the longer and shorter sounds. A comparison of the effect of slight differences in duration with slight differences in intensity lends support to this idea. If we rank the four subjects used in the investigation of the effect of intensity with respect to the magnitude of the quantity A–B for the two small intensity ratios of 30 to 24 and 32 to 24 (feet at which audible), and then with respect to the same quantity for small ratios of durations, we find that the correlation is perfect. In other words, if a slight difference in intensity produces a strong trochaic rhythm for any given subject, a slight difference in the duration of the sounds does also; whereas if a slight difference in intensity produces only a very weak trochaic, the same will be true of a slight difference in duration. I believe, therefore, that the trochaic rhythm produced by small ratios in the durations is due to the different effect as regards intensity of a long and short sound. Now this difference in apparent intensity should increase as the difference in duration increases. But after a certain comparatively short duration is reached, the increase in apparent intensity is very slow. It seems probable, therefore, that, in rhythms produced by short sounds, we have to deal with two separate factors, intensity and duration, even though the sounds differ physically only in duration. The effect of intensity is to make the longer sound begin the measure, an effect which may be spoken of as trochaic, whereas the effect of duration, as such, is to make the longer sound end the measure, which usually means an iambic effect. With a small difference in the absolute durations of the longer and shorter sounds, the effect of intensity is comparatively great; but as the longer sound is increased more and more, the intensity difference between the two sounds becomes less and less relative to the difference in the duration between the sounds. When the difference in duration is sufficiently increased, therefore, we find that the trochaic effect of intensity tends to disappear because of the iambic effect of duration, that is, we get trochaic rhythm with small ratios but tend more in the iambic direction with large ratios (the absolute duration of the short sound remaining constant).

This conclusion is further confirmed by the results on absolute duration. The difference in intensity between the longer and shorter

sounds for any given ratio of their durations will be smaller, the longer the short sound. And my results on the effect of absolute duration, presented in Table X, show that, if the ratio is kept constant, the rhythm becomes less trochaic or more iambic, as the absolute duration of the sounds increases.

The effect of the difference in intensity produced by a difference in duration may also explain in part at least the case of subject Dy, in which there was only a slight decrease in the trochaicness of the rhythm with an increase in the ratio between the durations. For, with Dy, differences in intensity had much more effect than with any of the other subjects investigated for the effect of variations in intensity. The greatest magnitude obtained for the quantity A–B, in the investigation of intensive differences with Dy, was 50% greater than the greatest magnitude of the same quantity for any of the other three subjects. Inasmuch as the effect of intensity is trochaic, we should expect to find the tendency towards iambic resulting from large ratios between the durations to be less in the case of Dy than in the case of the other subjects.

I have confined myself chiefly to the investigation of two-membered groups; but that the above mentioned general law concerning the effect of variations in the relative durations of the sounds holds for three-membered groups, as well as two-membered groups, is indicated by Table IX, where the quantity A–B changes from +.02 to —.06 with increase in the ratio of duration between the longer and the two shorter sounds. The method which was used here to determine the indifference point was to vary only the intervals immediately preceding and following the long sound. The two shorter sounds, both of equal duration, were kept the same distance apart throughout, being separated by an interval such that this interval plus the duration of one of the shorter sounds equals one-third the total duration of the measure. By the interval "before," is meant the interval before the longer sound; by the interval "after," the interval after the longer sound, as in the tables on rhythms made up of groups of two sounds.

TABLE IX

The Effect of Relative Duration on the Anapaestic-dactylic Indifference Point. Subject, Ww.

Duration of the two shorter sounds (constant) = 0.08 second. Total duration of measure = 2.0 seconds. Interval between the two shorter sounds (constant) = 0.58 second.

Longer sound	Before	After	N	*M V*	A—B	(A + L)—(B + S)
.16	.54	.56	10	*.013*	+ .02	+ .10
.30	.50	.44	11	*.024*	— .06	+ .16

Before proceeding to the discussion of the effect of variations in the absolute duration of the sounds, it is desirable to bring up the question of the effect of change in the duration of the intervals while the absolute and relative duration of the sounds remains unchanged. This is necessary inasmuch as, in the above tables, which show that there is a change in the iambic direction as the ratio of the durations increases, there occurs simultaneously with the increase in the ratio between the sounds a decrease in the total amount of silence within the group. The reason for this is that the total duration of the group was kept the same, and evidently, then, as one of the sounds was increased in duration in order to get bigger ratios, the total amount of silence remaining had to be decreased. The question might therefore arise as to whether the change noted above in the iambic direction was due to the increase in the ratio between the durations of the long and short sounds, or whether it was due to the decrease in the proportion of the total duration of the group occupied by silent intervals. I have not sufficient data to state in a definite way what is the effect on rhythm of variation in the duration of the intervals, the absolute and relative duration of the sounds remaining constant; but I have data to show that it is utterly impossible that the changes noted above, from trochaic to iambic rhythm with increase in the ratio of the durations of the sounds, could be due to the coincident decrease in the proportion of the total duration of the measure constituted by the intervals of silence. In the case of subject Wr, with a ratio of durations of 19 to 13, and equal intervals of .59 second, the quantity A–B = + .02 second; with the ratio 43 to 13, and equal intervals of .47 second, the quantity A-B = — .08 second, and with a ratio of 60 to 13, and equal intervals of .39 second, A–B = — .11 second. That this change of A–B from + to — (*i. e.*, change from trochaic to iambic rhythm) is not due to the shortening in the intervals is shown conclusively by the following table, where it is

TABLE X

Effect of Proportion of Sound to Silence on Iambic-trochaic Indifference Point

Subject, Wr.

Duration of shorter sound = .13 second.

Longer sound	Before	After	N	*M V*	A — B
.19	.58	.60	11	*.011*	+ .02
.43	.51	.43	17	*.023*	— .08
.60	.44	.33	19	*.024*	— .11
.43	1.19	1.25	14	*.047*	— .06
.60	1.07	1.20	18	*.025*	— .13
.72	.98	1.17	16	*.025*	— .19

seen that the intervals are in every case about twice as great as in the case of the ratio 19 to 13, where the intervals were .59 second and the rhythm trochaic, and yet the rhythm in these cases, too, becomes strongly iambic as the ratio between the sounds increases. Evidently the change in A-B from + .02 second to — .19 second, as the ratio between the durations of the sounds increases, can not be due to a decrease in the intervals of silence, for these have not decreased, but nearly doubled.

As regards the result of variation in the absolute duration of the sounds, the following table seems sufficient to establish beyond a doubt that in rhythms in which the sounds of a two-membered group are of different durations, with a given ratio of these durations the rhythm becomes more trochaic or less iambic as the absolute duration of the sounds decreases, and less trochaic or more iambic as their absolute duration increases. The effect of change in the absolute duration of the sounds is exceedingly great, so that it is impossible to say of any given ratio of durations that it will produce a certain rhythm, even in the same subject: the absolute, as well as the relative, duration of the sounds must be specified.

TABLE XI

Effect of Absolute Duration on the Iambic-trochaic Indifference Point

Subject, Ww.

Ratio between durations of long and short sound = 2 to 1.

Longer sound	Before	After	N	*M V*	A — B
.09	.63	.81	20	*.009*	+ .18
.25	.54	.58	16	*.011*	+ .04
.45	.41	.40	20	*.015*	— .01
.90	.87	.77	20	*.016*	— .10

In the above table, it is true that the intervals have not been kept constant, but enough has been stated already concerning the effect of intervals to show that the changes here shown from a marked trochaic to a marked iambic are due to changes in the absolute duration of the sounds.

A question of fundamental importance in the investigation of the effect of duration in rhythm concerns the proper method of presenting the results. Should the intervals between the sounds be treated separately, or should only the temporal distances from the beginning of one sound to the beginning of the next be considered? At first consideration, this question may seem to have little significance, at least in the present investigation, inasmuch as the duration of the sounds and intervals have been measured separately, and consequently it is possible to present the results

in both ways, and I have so presented them. And it is undoubtedly true that, if all we want is a description of what sort of rhythm is heard from any series of sounds, both the length of the sounds and the intervals between them, in case intervals exist, should be stated. But if we wish to understand or to explain our data, it is of great importance to know from what points to measure in presenting the results. For instance, should a rhythmical group be considered as being made up of "members" which extend, say, from the beginning of one sound to the beginning of the following? Dr. Brown, in his investigation of spoken verses writes: "On the whole I have decided to consider only the beginning of the syllables."[1] In the case of spoken rhythms or of any other rhythms in which the sounds are not of uniform intensity throughout, the question of measurement is perhaps more difficult than in the case of sound rhythms such as those used in this investigation. While in the present investigation the sounds were of uniform intensity throughout their length, it is yet possible that what really *counted* to the listener was neither the actual interval between the sounds nor the time elapsing from the beginning of one sound to the beginning of the next, but the interval between certain points of greatest subjective stress, the subjective stress being due, perhaps, to the occurrence, at certain points, of greater attention, of motor performances, or to unknown factors; and these theoretically possible points of greatest subjective stress might conceivably occur almost anywhere. The significance which is to be attached to any data concerning the objective conditions of rhythms in which variations in duration occur depends upon the mode of tabulating the results.

I have obtained some data which seem to me to solve this question concerning the proper treatment of results. As I shall show in Chapter VI, the temporal spacing of the sounds at the indifference point for rhythm very nearly coincides with that spacing at which all the intervals appear equal, a fact which justifies the conclusion that perception of rhythm and perception of time are closely allied processes. This being the case, it is possible to tell whether in rhythm the interval between the sounds or the interval from the beginning of one to the beginning of the following is the more significant by asking the subject, after having determined his indifference point for rhythm, to compare intervals, first asking him to compare the intervals between the beginnings of the sounds and then asking him to compare the silent intervals between the sounds. Of the two kinds of interval comparison, that one which gives results corresponding to the judgments on rhythm will be indicated as the

[1] *Archiv. of Psychol.*, No. 10, 28, 1908.

process more nearly allied to the process involved in judging of the rhythm; and consequently the more significant mode of tabulating the results will also be indicated. In other words, if the results concerning the indifference point for rhythm correspond with the results in determining the point where the intervals between the the sounds appear equal, and do not correspond with those where the intervals between the beginnings of the sounds appear equal, then the data concerning rhythm should be presented in a way which will make it clear what were the actual silent intervals between the sounds. Four subjects were tested in the above manner. It is unnecessary to insert at this point the detailed results of these tests, as the data are given in Chapter VI. In the case of three subjects, Dy, Ww, and Wr, it was found that the indifference point for rhythm corresponded with that for the comparison of the intervals from the end of one sound to the beginning of the following; while in the case of the fourth subject, Ws, the results on rhythm corresponded with the results on the comparison of intervals between the beginnings of the sounds. There is some ground, then, for the conclusion that usually the intervals which are most important in deciding what will be the nature of the rhythmical impression are the intervals between the end of one sound and the beginning of the following. But, in the case of Ws, there is no doubt that the rhythm judgment was more closely allied to the process of comparing the intervals between the beginnings of the sounds than to that of the comparison of the actual silent intervals. This conclusion is borne out by the following introspection: "I do not mean by intervals the time between the notes. The interval is the difference between the times when the two notes *strike*." Again, "Tones are more nearly of the same length as you approach the changing point, the point where iambic changes to trochaic. The *tones* differ but the *beats* don't." Again, after an hour spent in attempting to compare the actual silent intervals between the sounds, "It is funny, because it is hard to catch the end of a sound and measure intervals in such a manner." The subject plays the piano and organ, and is the only piano player, in fact, the only practical musician of any sort who took part in this investigation. In piano playing, of course, the beat producing any sound comes at the beginning of the sound, at least the greatest amount of tactual and kinaesthetic sensation would be received at the moment of pressing down the keys; moreover, in music, especially organ music, there are practically no silent intervals between the sounds. These considerations suggest that possibly the reason why the judgments on rhythm corresponded in this case with judgments on the intervals

between the beginnings of the sounds was that there was in this case a motor performance coinciding with the beginning of the sounds, a performance which may have been absent, insignificant, or of a different character in the case of the other subjects. The importance of motor phenomena in the origin of the impression of rhythm has been sufficiently emphasized by previous authors.

The results of this investigation show very plainly the significance of this question concerning the treatment of results. If we consider the two-membered group made up of two periods, each extending from the beginning of one sound to the beginning of the next, it is true without exception that, when these periods are equal, the rhythm is heard as trochaic, and, providing these periods are kept equal, the rhythm becomes more and more trochaic as the ratio between the durations of the sounds increases. Thus, while in the case of the ratio of durations of 2 to 1, with a rather long absolute duration of the sounds, say a duration of the shorter sound equal to .40 second, we might expect to find the rhythm strongly iambic if the intervals between the sounds were equal, it would without question be heard as trochaic if the intervals between the *beginnings* of the sounds were equal. No subject was found, in this investigation of rhythms produced by variations in duration only, who in any case obtained iambic rhythm from any series of sounds, the intervals between the beginnings of which were equal. As long as the intervals between the beginnings of the sounds are equal, the rhythm becomes more and more trochaic with an increase in the ratio of the duration of the longer sound to that of the shorter. In some subjects, this increase in trochaism is very nearly proportional to the increase in the ratio of the durations, in others, it is less rapid. It seems, therefore, impossible to state the exact relation between the increase in the ratio of durations and the increase in the temporal segregation of the group (in this case, the increase in trochaism) until the causes of individual differences can be quantitatively estimated.

CHAPTER VI

The Meaning of Rhythmical Grouping

Every one is agreed today that the essential thing in the perception of rhythm is the experiencing of groups. It is this experience of groups which distinguishes rhythm in the psychological sense of the word from rhythm in the sense of a regularly recurring event, such as the revolution of the earth about its axis. Thus, Meumann writes that the large number of well-trained observers, which he used in his investigations of rhythm, gave without exception the introspection that a subjective binding together of the impressions into a whole is inseparable from the simplest case of the perception of rhythm.[1] Bolton found in the case of every one of thirty subjects that grouping was the irremissible sign of rhythm. And Miner states at the outset of his treatise on rhythm that he uses the word rhythm only in the sense of rhythmic grouping.

But, while all recent writers on rhythm recognize that the experience of groups is an essential factor in the experience known as the perception, or the feeling, of rhythm, there is wide diversity of opinion as to what we mean when we speak of the members of a series of impressions as being experienced in groups. I am unable to judge just to what extent this diversity of opinion goes, because of the impossibility of ascertaining, in the case of many writers, whether they are referring to the experience of groups, or to the causes of this experience—whether they are describing a state of consciousness, or presenting a theory as to the origin of this state. To give an example, Bolton writes as follows: "The conscious state accompanying each wave of attention grasps together or unifies all the impressions that fall within the temporal period of the wave."[2] If he had written merely that the attention wave grasps the impressions together, one would believe that he was talking of the origin of the group experience; but when he says that it is the *conscious state accompanying* the attention wave, it seems as though he was giving an introspective description of the group experience. Some of the interesting introspections reported by Bolton show the same ambiguity. He says of himself, "The puffs of a locomotive may now be grouped by two or three, but the association of the drive-wheel making one revolution to four sounds renders any other form of grouping than by four difficult."[3] In

[1] *Phil. Stud.*, 10, 271, 1894.

[2] *Amer. Journ. of Psychol.*, 6, 220, 1894.

[3] *Ibid.*, p. 205.

this case, did the idea of the drive-wheel, like the conscious state accompanying an attention wave, grasp or tend to group four impressions together, and so produce a grouping or did the group experience consist merely in the simultaneous experience of the four impressions and the idea of the drive-wheel making one revolution? The introspections by his subjects are also often ambiguous, for instance, the introspection of subject No. 12, of whom Bolton writes: "As to the nature of the group, the subject described his feelings as a tendency to go back when he had heard three or four clicks, as the case might be. He says he has a 'mouthful'—a unity—and when he has one, he seeks to get another."[1] Another subject "noticed rhythms in the sound of mill wheels. When he gave his attention to these sounds he visualized a series of points on a line which he counted by four or two. When he was asked to count a series of dots he said they were divided off into twos by a bracket above them."[2] In this case, the meaning of rhythmical grouping seems to be a grouping by brackets, the idea of bracketed points existing, apparently, more or less simultaneously with the percepts of the mill sounds. Subject No. 7 described some of his groupings as though grouping merely meant counting to eight. At times, Bolton seems to consider that the grouping is a temporal grouping, as when he writes as follows: "The weaker or less accented sounds seem to run together with the stronger, and to form organic groups which are separated from one another by intervals which are apparently longer than the interval which separates the individual clicks."[3] But Bolton nowhere tries to show how "the conscious state accompanying each wave of attention" causes the impressions which it unifies to appear separated by shorter intervals than the intervals separating two successive impressions which fall in different waves, *i. e.*, in different groups.

Meumann writes that for many observers the grouping was always temporal, a temporal holding together, in which the members of the groups appear to follow quicker upon each other, while between every two groups lies a pause.[4] He regards grouping as an intellectual act, which shows itself in the subordination of certain impressions to others, for instance, the subordination of the more intense to the less intense. In verse, however, Meumann

[1] *Amer. Journ. of Psychol.*, 6, 196, 1894.

[2] *Ibid.*, p. 198.

[3] *Ibid.*, p. 204.

[4] *Phil. Stud.*, 10, 283 and 304, 1894.

says that grouping may be conditioned entirely by meaning.[1] In this case, then, rhythmical grouping means logical unity.

The position of McDougall seems to be that a rhythmical group is an awareness of a temporal segregation of the impressions. "The whole group of elements constituting the rhythmic unit is present to consciousness as a single experience; the first of its elements has never fallen out of consciousness before the final member appears, and the awareness of intensive differences and temporal segregation is as immediate a fact of sensory apprehension as is the perception of the musical qualities of the sounds themselves."[2] At other times, he seems to regard the grouping as the experiencing of impressions along with the experience of an ideal form, or "Gestaltsqualität," as when he speaks of the experience of rhythm as being supported by the conception of an ideal form which the series of stimuli fulfils.[3] He says further that the synthesis of elements may be mediated by changes in the ideal significance and relation of the various members; also by movements of the head, jaw, throat, eyes, or by muscular strain;[4] but he does not show how these changes in ideal significance or these movements of various parts of the body produce temporal segregation.

The view has been put forth by several recent authors that the rhythmical group consists in the experience of muscular strains along with the experience of the other impressions, such as a series of sounds. According to this view, a rhythmical group may be thought of as a series of impressions strung together by one longer state of strain, much like fish strung together on a string; as when Miner speaks of the separate sensations from the external world as being strung in groups. Stetson represents this view when he says that "the continuity of the rhythmic series, whereby all the beats of a period seem to belong to a single whole, is due to the continuity of the muscle sensations involved and the continuous feeling of slight tension between the positive and negative muscle sets;[5] nowhere within the period does the feeling of strain die out." Similarly, Miner says that "feeling the groups to be units is an illusion due to the presence of movement or strain sensations along with the sensations that are grouped." "These kinaesthetic sensations provide the factor by which unit sensations ap-

[1] *Phil. Stud.*, 10, 396, 1894.

[2] *Harvard Psychol. Stud.*, 1, 1903 and *Monog. Sup. Psychol. Rev.*, 4, 322, 1903.

[3] *Ibid.*, p. 468.

[4] *Ibid.*, p. 343.

[5] *Harvard Psychol. Stud.*, 1, 1903 and *Monog. Sup. Psychol. Rev.*, 4, 455, 1903.

pear bound into groups."[1] In speaking of visual rhythms, however, he says: "The units in the group seem crowded closer together and a longer interval appears before the next group starts."[2] This indicates that the grouping is temporal. We might expect, therefore, some attempt on the part of the author to show that strain sensations, which are said to hold the impressions together, cause an underestimation in time; he makes no such attempt. And while it might possibly be held that strain sensations and the perception of time are identical, such a theory would rather lead us to expect the strain sensations to force the separate impressions apart from each other rather than hold them together, because according to any theory which makes strain sensations the basis of the perception of time, the greater the strain sensations during any interval, the greater the apparent duration of that interval.

As I have already stated, in the present research in all the work done on the effect of duration and intensity on rhythm, the subjects were instructed to judge concerning the rhythm, and nothing was said to them concerning intervals. In order to obtain some idea of the nature of the rhythmical group, however, after the work on rhythm was all over, I carried on some investigations on the effect of the same variations in intensity and duration that I had used on rhythm on the apparent length of the intervals. The indifference points of which I have spoken in the chapters on intensity and duration were indifference points for rhythm. This rhythm indifference point should not be confused with what is spoken of as the indifference point in the comparison of intervals. The instructions given the subject and the experimental procedure used in obtaining the various rhythm indifference points have already been described. The procedure for obtaining the point at which all the intervals appear equal, that is, for obtaining the indifference points in the comparison of intervals, was in every respect the same as that used in the study of the indifference point for rhythm; but the instructions given the subject were different. In obtaining the indifference point for intervals, the subject was asked to ignore the rhythm, and (every second sound being more intense or longer) to judge merely whether the interval preceding the louder or the longer sound was greater, equal, or less than that following it.

When there is much of a difference in the duration of the sounds, the subject's idea of what is meant by intervals will evidently have a great influence on the results obtained. If the word interval

[1] *Monog. Sup. Psychol. Rev.*, 5, No. 4, pp. 2, 20, 1903.

[2] *Ibid.*, p. 5.5.

means to the subject the time between the *beginnings* of the sounds, the indifference point for the comparison of intervals will be quite different from what is obtained when the subject is asked to consider the intervals which exist between the sounds. No instructions were at first given to any of the subjects concerning what they should consider to be the interval, as it was desired to see what they did naturally. Rather curiously none of the subjects seemed in any doubt as to what intervals to compare. The possibility that interval might mean anything but one thing never occurred to them, unless it was pointed out to them; and yet one of the subjects, Ws, started in to compare the intervals between the beginnings of the sounds, while three others compared the intervals of silence between the sounds. In all four subjects the results obtained by the comparison of intervals, leaving the subject to follow his own ideas concerning the meaning of intervals, gave as the indifference point for the comparison of intervals in any given series of sounds practically the same point which had been previously obtained as the rhythm indifference point for the same series. As long as the subjects compared intervals in the way which seemed most natural to them, their results for the interval indifference point and the rhythm indifference point corresponded very closely; but when subject Ws was asked to compare actual intervals, results were obtained very different from the results obtained on the rhythm indifference point; and when subjects Dy, Ww, and Wr compared the intervals between the beginnings of the sounds, the interval indifference points thus obtained diverged widely from the corresponding rhythm indifference points. By "before" and "after" in the following table is meant, as usual, the actual intervals of silence before and after the longer sound.

TABLE XII

Duration of shorter sound (constant) = 0.13 second. Total duration of measure = 1.5 seconds.

Subject	Longer sound	Intervals at indifference point		Nature of indifference point
		Before	After	
Wr	.60	.44	.33	rhythmic
Wr	.60	.46	.31	silence
Wr	.60	.55	.22	beginnings
Ws	.60	.54	.23	rhythmic
Ws	.28	.55	.54	rhythmic
Ws	.28	.54	.55	beginnings
Ws	.28	.45	.64	silence
Ww	.37	.51	.49	rhythmic
Ww	.37	.51	.49	silence
Ww	.37	.58	.42	beginnings

Results are presented for three different sorts of indifference point, the iambic-trochaic indifference point, the indifference point for the comparison of the actual intervals of silence between the end of one sound and the beginning of the following sound, and the indifference point for the comparison of the intervals between the beginnings of the sounds. These three sorts of indifference point are referred to in the column headed "nature of indifference point," as "rhythmic," "silence," and "beginnings."

The comparison of intervals thus affords a method of determining what intervals are the most significant in rhythm, for, evidently, if comparing intervals in one way gives results the same as obtained in judging rhythm, while comparison in a second way gives widely different results, the process of judging of the rhythm must be more closely allied to the first way of comparing intervals than to the second.

TABLE XIII

Intensity of weaker sound (constant) = 24 feet.

Subject	Intensity of louder sound	Duration of every sound	Indifference point for interval comparison				Indifference point for rhythm (iambic-trochaic)			
			N	*M V*	Before	After	Before	After	N	*M V*
Ww	136	.13	19	*.037*	.57	.66	.55	.68	21	*.015*
Ww	136	.22	15	*.026*	.94	1.11	.90	1.16	10	*.022*
Ww	136	.31	10	*.033*	1.31	1.56	1.29	1.58	10	*.021*
Ww	136	.45	16	*.028*	1.92	2.17	1.91	2.19	14	*.041*
Ww	136	.68	16	*.055*	2.93	3.22	2.97	3.18	6	*.104*
Ww	136	.07	14	*.008*	.30	.32	.26	.36	10	*.010*
Ww	136	.09	14	*.011*	.36	.46	.37	.46	12	*.006*
Ws	28	.13	11	*.018*	.62	.62	.61	.62	20	*.022*
Ws	32	.13	10	*.018*	.60	.63	.59	.64	20	*.012*
Ws	70	.13	10	*.018*	.60	.63	.58	.65	20	*.021*
Ws	196	.13	15	*.010*	.60	.63	.57	.66	56	*.025*
Ws	300	.13	10	*.012*	.58	.65	.57	.66	41	*.021*
Ws	1100	.13	10	*.015*	.56	.67	.55	.68	38	*.018*
Wr	136	.13	18	*.010*	.58	.65	.56	.68	10	*.010*
Wr	1100	.13	11	*.016*	.54	.69	.51	.72	17	*.016*
Dy	136	.13	19	*.019*	.58	.65	.51	.72	15	*.016*
Dy	420	.13	14	*.024*	.48	.75	.50	.73	10	*.014*

The results obtained on the indifference point for the comparison of intervals, are shown in Tables XIII and XIV, in which are also given the results on the rhythm indifference point for the same ratios of intensities and durations of the sounds. In Table XIII, results are presented for sound series in which all the sounds of a series were of the same length but every other sound the louder.

In Table XIV results are presented for series in which the sounds were of equal loudness but every other sound the longer. In the columns headed "before" and "after" are given the duration, at the indifference point, of the intervals before and after the longer or the more intense sound.

TABLE XIV

Intensity of all sounds = 24 feet.

Subject	Duration of longer sound	Duration of shorter sound	Indifference point for interval comparison				Indifference point for rhythm (iambic-trochaic)			
			N	*M V*	Before	After	Before	After	N	*M V*
Ws	.28	.13	10	*.009*	.53	.56	.55	.54	24	*.020*
Ww	.37	.13	15	*.015*	.51	.49	.51	.49	15	*.016*
Ww	.61	.22	12	*.022*	.76	.90	.75	.91	12	*.018*
Ww	.86	.30	8	*.028*	.98	1.34	1.00	1.32	14	*.028*
Ww	1.23	.43	6	*.033*	1.53	1.80	1.47	1.86	6	*.028*
Ww	1.65	.65	6	*.030*	2.35	2.65	2.21	2.79	6	*.037*
*Dy	.37	.13	12	*.019*	.43	.57	.40	.60	10	*.045*
Wr	.19	.13	10	*.010*	.58	.60	.58	.60	11	*.011*
Wr	.25	.13	9	*.010*	.54	.58	.54	.58	16	*.018*
Wr	.31	.13	15	*.017*	.52	.54	.53	.53	17	*.011*
Wr	.43	.13	15	*.018*	.47	.45	.51	.43	17	*.023*
Wr	.60	.13	13	*.027*	.46	.31	.44	.33	19	*.024*

*In this case the longer sound had an intensity of 70 feet.

The results show that the absolute and relative durations of the intervals at the iambic-trochaic indifference point are almost the same as when the two intervals (the intervals before and after the louder or the longer sound) appear to be equal in length. The rhythm indifference points and the interval indifference points are almost, but not entirely, identical. If we term the differences in the durations of the intervals before and after the louder or the more intense sound constant errors, then it may be said that considering both Tables XIII and XIV together, most frequently the constant errors are less when the subject judges intervals than when he judges rhythm. In the case of series in which the sounds present only duration differences, however, there seems to be no reliable difference, as in Table XIV the constant errors for rhythm are in five cases greater, in three cases the same, and in four cases less than the constant errors for comparison of intervals. In Table XIII, however, it is fairly evident, perhaps, that the constant errors due to differences in the intensity of the sounds are usually slightly greater for the rhythm indifference points than for the interval indifference points, as the constant errors for the rhythm

judgments are greater than those for the interval judgments in fourteen cases and less in three cases. The two sets of results are not exactly identical, but they are so close to it that the conclusion seems fairly safe that they are the result of mental operations which have about the same basis. In other words, the statement by the subject, that certain sounds form an iambic group, is equivalent to the statement that he has perceived a shorter interval before the louder or the longer sound than after it, and the statement that the sounds form a trochaic group means that the subject has perceived a shorter interval after the louder or longer sound than before it. This is the equivalent of saying that the experiencing of a rhythmical group is an experiencing of temporal relations, that the meaning of rhythmical grouping is temporal segregation. This conclusion in no way implies that the subject makes judgments concerning intervals whenever he hears rhythm, but merely that he perceives these intervals. Nor does it imply that in comparing intervals one necessarily judges of rhythm; nor possibly, even, that he has experienced rhythm, since it has never been proved that the immediate experience of a temporal grouping is of itself all that is necessary for the experience of rhythm.

In the hope of making clearer the relation between the perception of a temporal grouping and the perception of rhythm, I cite a few introspections. They are quoted literally, and are to be treated as data requiring interpretation, and not accepted at their face value. Subject Br: "The rhythmical grouping seems a temporal grouping without attention being paid to the temporal relations at the time the rhythm is heard." Subject Wr was asked, after his first hour of work in comparing intervals, which intervals he had been comparing, the intervals between the beginnings of the sounds or the intervals of silence between the sounds. He replied that he did not know which he had been doing. Subject Dy: "Rhythm is not always present in comparing intervals, but it sometimes comes. At such times it seems difficult to judge intervals without the rhythm being the predominating factor. The rhythm I notice in comparing intervals is not always the same as when I put my attention on the rhythm itself, *e. g.*, if I get a trochaic rhythm while judging intervals, and then turn my attention to the rhythm I sometimes get iambic instead. An iambic never changed to a trochaic in this way." Ws: "Rhythm becomes apparent to the ear by unequal lengths of sound. The short intervals come between the sounds which make the rhythm and the long intervals between the groups of sounds." At another time, "When the loudest and longest note comes first, I put down tro-

chaic; but when it comes at the end of each rhythm, I put down iambic. I do not notice the length of intervals especially." Same subject, summer, '07: "When there is absolutely no difference in the length of intervals, the rhythm is trochaic." Summer, '08: "In comparing the intervals, the intervals are equal in iambic rhythm." After an experiment in which this same subject was asked to judge in the case of each sound series, first, whether the rhythm was iambic, doubtful, or trochaic, and second, whether the intervals were equal or unequal, and if unequal whether the interval before or after the louder sound was the longer: "In keeping a record of both rhythms and intervals I went through two different processes of judgment; the two judgments did not seem alike. I had never before realized that the doubtful rhythms were those where the intervals are equal."

The very slight difference already noted as existing between the interval indifference point and the indifference point for rhythm does not seem large enough nor reliable enough to invalidate the conclusion that the grouping referred to when we speak of rhythmical grouping is a temporal grouping. What slight tendency there is for constant errors (in the sense used above) to be smaller when the subject judges of intervals than when he judges of rhythm seems to me to indicate merely the effect of the different attitude on the part of the subject in the two cases, the difference being, to judge from my own introspection, that, in comparing intervals, both sounds are about evenly attended to, there is a comparatively continuous strain, while in judging rhythm, some of the sounds, *e. g.*, the more intense, are attended to more than others. Such a view enables us to understand the statement of Meumann that his subjects only judged the interval between the groups as longer than the intervals within the group, when they did not set out especially to judge intervals ("Wenn sie nicht darauf ausgehen, die Intervalle bewusst zu vergleichen."[1])

We are now in a position to understand in what consists the grouping effect of duration and intensity, and consequently their rhythmical effect in so far as rhythm consists in grouping. A regularly recurring more intense sound has the effect of increasing the temporal value of the interval preceding it as compared with that following it. This means that if the intervals are equal the sounds appear temporally grouped in such a way that the interval preceding the more intense sound separates the group, that is, that the sounds, if heard as rhythm, produce the impression of trochaic rhythm. This effect of the more intense sound may therefore be

[1] *Phil. Stud.*, 10, 304, 1894.

spoken of as trochaic. The regularly recurring more intense sound continues to exert this effect even though, because of an objective shortening of the interval preceding the more intense sound, the rhythm is heard as iambic. The more intense sound is exerting an influence towards trochaism even when it occurs in an iambic rhythm. Similarly, if the distinction between the duration effect *per se* and the intensity effect of an increase in duration be admitted, the results obtained on duration show that a regularly recurring shorter sound also exerts a trochaic influence, and this, too, whether the rhythm is heard as iambic or trochaic. In referring to the trochaic effects of the shorter and the londer sounds, I am speaking relatively. I mean that the effect of the regularly recurring shorter or louder sound is trochaic compared to the effect of the weaker or the longer sound. It is equally true, of course, if we are speaking relatively, to say that an increase in duration or a decrease in intensity exerts an iambic effect, or causes an underestimation of the interval preceding the longer or the weaker sound.

SUMMARY

It is possible to pass from one rhythmical grouping to another by changing the relative duration of the intervals between the sounds. Thus, a trochaic rhythm, that is, one that is composed of groups of two sounds each, the louder sound beginning the group, may be changed to an iambic rhythm, one in which the louder sound ends the group, by increasing the interval immediately following the louder sound or by decreasing the interval immediately preceding it. Similarly, a rhythmical group which begins with a sound longer than the other sounds of the group may be changed to one in which the longer sound ends the group by increasing the interval immediately following the longer sound, or by decreasing all the other intervals. As we pass in this way from rhythmical groups beginning with the louder or longer sound to rhythmical groups ending with that sound, we pass through a zone where the tendency towards the two forms of grouping is equally strong. The middle point of this zone may be termed the rhythm indifference point. If the rhythm indifference point occurs where all the intervals are objectively equal, then any differences which may exist in the objective duration or loudness of the sounds are obviously not exerting any effect towards grouping. But if, when the intervals between all the sounds are objectively equal, grouping is still perceived, the grouping must be regarded as brought about by other factors than objective differences in the intervals. The amount of this grouping effect can be determined by finding out what change from objective equality of intervals is necessary in order to cause the grouping to disappear, that is, by ascertaining the amount by which one of the intervals has to be lengthened or shortened with respect to the others in order to arrive at the rhythm indifference point. We may say, therefore, that the influence towards rhythmical grouping exerted by factors other than objective differences in the intervals, that is, by such factors as recurrent differences in accent, duration, pitch, etc., is measured by the difference, at the rhythm indifference point, between the external and internal intervals of the group.

When the intervals are equal, and every second stimulus the stronger, the rhythm is trochaic, and when every third is the stronger, dactylic. That is, a regularly recurring difference in intensity exerts a tendency towards rhythmical groups with the more intense sound at the beginning. In other words, accenting certain sounds of a series has the same effect on the position of those sounds within

the rhythmical group as objectively increasing the interval preceding them. For instance, if the sounds corresponding to the odd numbers of an equally spaced series be accented, those sounds appear to begin the groups; and similarly, without accenting them, but by sufficiently increasing the interval immediately preceding them, they may be made to begin the groups.

This trochaic or dactylic effect caused by an increase in the relative intensity of every second or every third sound, that is, the tendency of the accented sound to begin the rhythmical group, may be measured by the amount by which the interval immediately following the stronger stimulus has to be increased in order to arrive at the rhythm indifference point: and in this way the effect on rhythm of variations in the relative intensity of the sounds may be studied. *With an increase in the ratio of the intensity of the louder sound to that of the weaker, there is an increase, first rapid and then slow, in the tendency of the more intense sound to begin the group.* In other words, with equal intervals, as the difference in intensity between the louder and weaker sounds increases, the intensity of the weaker sound remaining constant, the rhythm becomes more and more trochaic, if composed of two-membered groups, or more and more dactylic, if composed of three-membered groups.

I have stated that the rhythmical effect exerted by regularly recurrent accents is measured by the difference between the internal and external intervals of the group at the indifference point. This is an absolute measure. By dividing this by the total duration of one measure we get a relative measure, that is, a measure of the rhythmical effect relative to the total duration of one measure. In comparing the rhythmical effect of intensity, duration, etc., in sound series which are run off at different rates, the relative measure is what should be taken into consideration. The rhythmical effect of any given ratio of intensities between the louder and weaker sounds, relative to the rate at which the series is run off, remains constant, in two-group rhythms, for rates varying approximately from one to four seconds for one measure, usually shows a marked decrease by the time a rate of seven seconds for one measure is reached, but in some cases does not entirely disappear at a rate of ten seconds for one measure.

Measurements of the rhythmical effect of changes in the relative and absolute duration of sounds, made by the same method as that used in the case of intensive differences, lead to the following generalizations. *With an increase in the ratio of the duration of the longer sound to that of the shorter, there is an increase in the tendency of the longer sound to end the group or a decrease in its tendency to*

begin the group. When the ratio of the duration of the longer sound to the duration of the shorter is small, that is, when there is not much difference in the duration of the sounds, and when, further, the absolute duration of the sounds is also small, the longer sound tends to begin the group. A small regularly recurrent increase in duration, then, may have the same effect, providing the absolute duration of the sounds is small, as a regularly recurrent difference of accent. But whereas an increase in relative intensity has the effect of *increasing* the tendency of the accented sound to begin the group, an increase in relative duration has the effect of *decreasing* the tendency of the longer sound to begin the group, and often results in an exceedingly strong tendency on the part of the longer sound to end the group.

If all intervals are kept equal, and every second sound is somewhat longer, we may have a trochaic rhythm. This seems at first sight to indicate that the effect of a slight increase in duration is a trochaic tendency whereas the effect of a considerable increase is an iambic tendency. It is necessary, however, to make a distinction between duration *per se* and the increase in apparent intensity of a stimulus due to an increase in duration. The apparent intensity increases as the duration, at first fast but later very slowly. The difference in the apparent intensity of a sound one second in duration and of a sound two seconds in duration is small, very small compared to the difference in duration. The difference in apparent intensity of a sound one-fiftieth of a second in duration and a sound two-fiftieths of a second in duration is very great, even in comparison with the increase in apparent duration. As we increase the duration of every second sound, therefore, we have two separate and antagonistic effects to keep in mind. First, there is an increase in the tendency of the longer sound to *begin* the group, due to the effect of duration on apparent intensity: second, there is a much more rapid increase in the tendency of the longer sound to *end* the group, due to the effect of an increase in duration *per se.* The increase in the second tendency is so much faster than that in the first, that the second may overcome the first, when the increase in duration is great, even though the first tendency may have been the stronger when the increase in duration was small.

The difference in the apparent intensity between two sounds due to a difference in their duration decreases, compared to the difference in apparent duration, as the absolute duration of the sounds increases. As the absolute duration of the sounds is increased, then, the trochaic effect of duration due to the effect of

duration on intensity should decrease relatively to the iambic effect of duration as such. And measurements show that, in fact, *with a constant ratio between the durations of the sounds, as their absolute duration increases, there is a decrease in the tendency of the longer sound to begin the group or an increase in its tendency to end the group.*

The effect of both intensity and duration in rhythm may be generalized as follows. If every second or third sound is made more intense or is made shorter, the effect on grouping is the same as if the interval immediately preceding that sound were increased relative to the other intervals. The effect of the more intense sound, when all the sounds are of equal duration, or of the shorter sound, when all the sounds are of equal intensity, is a relative overestimation of the interval preceding the more intense or the shorter sound. There is an objection to speaking of an overestimation of any interval, however, in that the subjects in the experiments so far considered were not estimating intervals, but were judging rhythm. But when the subjects were instructed to estimate intervals, it was found that, in fact, *the interval preceding the regularly recurrent more intense sound or the regularly recurrent shorter sound is relatively overestimated.* The rhythm indifference point and the indifference point for the estimation of intervals are almost, though not exactly, identical. This close correspondence between the rhythmical grouping and the temporal grouping, or rather this correspondence in the points where both disappear, indicates that rhythmical grouping is a temporal grouping; that is, that rhythmical grouping is determined by the duration of the subjective intervals, not by the objectively measurable intervals, but by the subject's consciousness of these intervals, that is, by the intervals considered as mental magnitudes.

VITA

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